



Electrification

▶ Battery Manufacturing 2030: Collaborating at Warp Speed

What it takes for equipment manufacturers to
ride the coming wave of breakneck growth



Battery Production



Robotics + Automation

Porsche Consulting
Strategic Vision. Smart Implementation.



INSIGHTS

//01

Industrial clusters serve as cornerstones of generating economic prosperity. The burgeoning battery industry presents an opportunity to establish a new foundational sector within the Western economy.

//02

Similar to many industrial clusters, mechanical and plant engineering is of pivotal importance. The emergent battery industry offers numerous possibilities for technological innovation.

//03

Despite a deceleration in the global economy, the battery sector boasts impressive annual growth rates exceeding 30 %, representing a vital avenue for economic expansion in both Europe and North America.



CONTENTS

Executive summary	04
Preface	05
01 A new sector rises: the € 550 billion growth opportunity	06
02 The battery sector's strategic value chain	11
03 Six waves: from a local to a global sector	15
04 The battery market tsunami: how to ride a dizzying growth curve	22
05 Decision time: the criteria for picking an equipment manufacturer	32
06 A to-do list for equipment manufacturers	37
07 How to get from 8 % to 20 % or beyond: possible market share scenarios	45
Appendix	53
Glossary	53

EXECUTIVE SUMMARY



The mobility and energy transition offers an unprecedented opportunity as the battery cell market is quickly racing from € 20 billion to € 550 billion in less than a decade. Equipment manufacturers stand the chance to benefit from this boom if they can outpace the competition and grow at the dizzying rate of 50 % CAGR. Even holding on to their current market share will require a rapid 35 % CAGR.

The crucial question is whether a second battery cluster will arise outside Asia. Currently, Asia holds a 92 % market share in battery manufacturing equipment, while Europe only has 8 %, meaning that Asian companies define the industry standard. To grow to 20 % market share—which is a precondition for a second, viable cluster—European and North American manufacturers, equipment suppliers and public entities need to come together and collaborate. Failing that, Asia will strengthen its lead and stay beyond 90 % equipment market share, preventing a second cluster from forming.

Rising to this challenge requires new forms of collaboration between all stakeholders. German Mittelstand needs to adopt to a new business mindset on a global stage. Players in Europe and North America need to work together, as do cell OEMs and equipment manufacturers. Lastly, equipment manufacturers need to partner and collaborate amongst themselves. The task of working together is intensified by the sheer scale, speed, and complexity of addressing technological and structural challenges.

With great challenges come outsized rewards. Equipment manufacturers can unlock a market worth up to € 300 billion until 2030 and make a meaningful contribution to the transition to a green economy. In addition, manufacturers will be able to solve the equipment bottlenecks impacting battery production going forward and to play an essential role in securing technological sovereignty by making a second, viable cluster for battery cell production outside Asia become a reality.

PREFACE



Everyone wants and needs batteries, that much is certain—but who will be the one to build the machinery to produce them?

Equipment manufacturers have long been the essential core of many industries, particularly in Europe. Their formula for success has been to closely work with industrial clusters, giving them the expertise they can now bring to the table as the new battery sector takes shape. This new sector must still solve several innovation challenges to be able to produce batteries in a better and cheaper fashion. Equipment manufacturers possess the strengths to significantly contribute to this innovative quest with battery machinery “made in Europe.”

The quickly rising battery sector offers a dramatic and dizzying growth opportunity, yet it also calls for acting with unprecedented speed and agility. It creates the dilemma of adhering to established standards, which imply never touching a running system, while at the same time being open to innovative approaches. Currently, the standard for battery production equipment has been defined by Asian incumbents who provide those running systems, giving them a 92 % global market share. This clear dominance prevents Europe and North America from enjoying technological sovereignty.

Acquiring technological sovereignty demands new approaches, operating at “China speed” and even faster, plus establishing new ways to partner and collaborate. The reward for making these changes lies in unprecedented growth and value creation while managing various sizable risks.

With this study we want to take the discourse, which is already happening inside many companies, to a broader audience. We know of multiple examples for equipment manufacturers that demonstrate that annual growth rates of 70 % are achievable. In addition, we want to encourage all stakeholders to seek out new ways to reach a market share of 20 % or more and thereby create technological sovereignty—a goal that can only be achieved through collaboration and standardization.

Successfully managing growth in a new sector is a value in and of itself. Even if establishing technological sovereignty in battery production were to prove elusive for European and North American manufacturers, individual companies would still be able to accomplish massive growth and extraordinary success.

**The task at hand
is complex and
challenging, at times
perhaps even daunting,
but it’s worth putting our
best foot forward and
going for it!**



A NEW SECTOR RISES: the € 550 billion growth opportunity

01

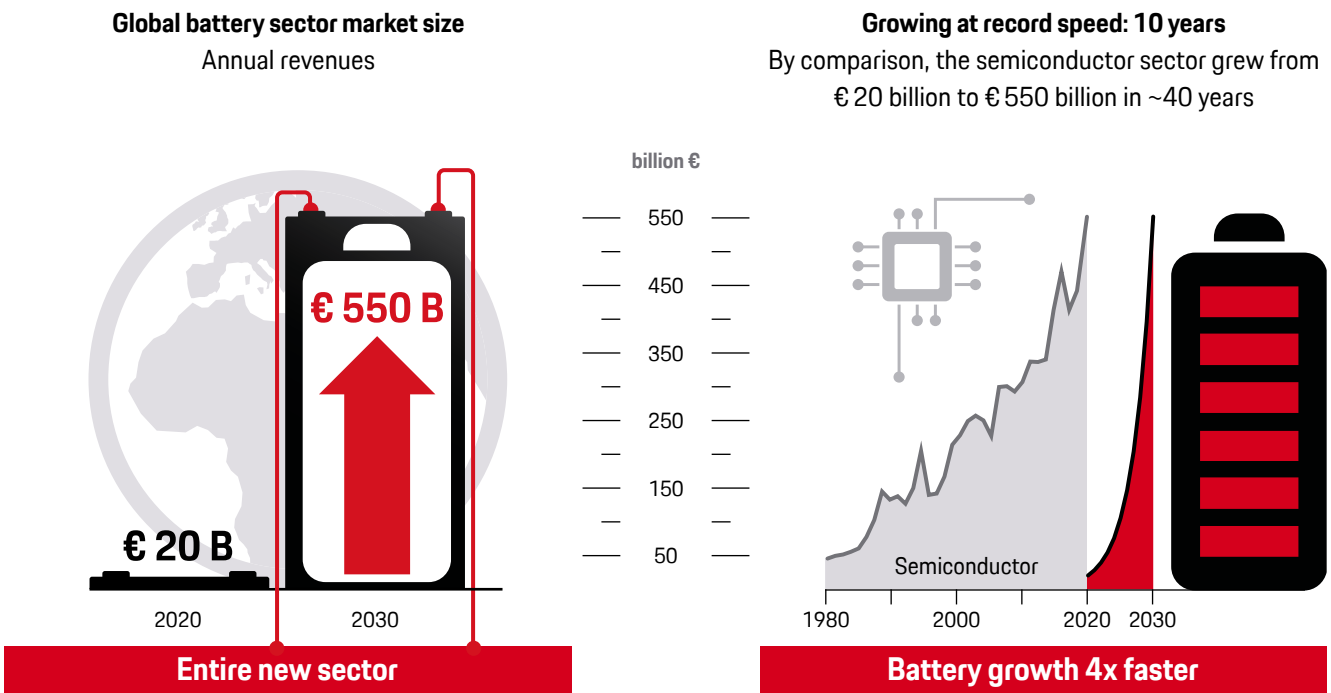
A new sector rises: the € 550 billion growth opportunity

The battery sector—comprising cell manufacturers, materials including mining, refining, and active materials, equipment manufacturers, and other players around systems—is growing at record speed, surging from € 20 billion in the beginning of the decade to an estimated € 550 billion by 2030.

It is rare that we can observe a new sector worth hundreds of billions of euros emerging in almost real time. Batteries, which are enabling and driving the energy and mobility transition currently underway, are not only a booming business with a dizzying growth rate. They also raise important questions concerning energy security and industrial policies in the EU and North America.

THE MARKET

The new sector's rapid growth eclipses the semiconductor market, which in 2022 had reached a similar size. While semiconductors took 40 years to reach the € 550 billion mark, the battery sector will make the leap in just a decade, presenting an astounding growth opportunity with a CAGR of 30




© Porsche Consulting

Fig. 1. A new sector rises at record speed: the 550 billion growth opportunity. Source: Porsche Consulting, SIA

to 40% or more. Over the coming 80 months until the end of 2030, announcements by followers and leaders show that more than 200 battery factories are planned to be constructed around the world, at a clip of roughly 2.5 new plants every month. This unprecedented growth rate, riding what we'd like to call a "curve of insanity," means that an equipment manufacturer with € 100 million in revenues in 2023 will reach revenues in excess of € 1 billion by 2030. It is an unprecedented but also challenging prospect.

The energy transition is the key demand driver, with electric vehicles (cars, trucks, buses, etc.) as the biggest segment. The lion's share of battery sales—86%—goes to mobility applications, with another 12% to stationary energy storage for residential and commercial or industrial settings. Consumer electronics, once the sole customer base for batteries, only make up 2% of battery demand.



Achieving energy security also depends on ample storage of batteries and hydrogen (H2). Wind and solar power can only cover electricity demand if they are paired with sufficient storage capacity. The solar industry is already dependent on Asian suppliers to meet its requirements, raising crucial questions about the future of the energy transition.



THE CLUSTER

The battery sector is a cluster of interconnected players, similar to other industrial clusters like the automotive cluster, comprising at its core cell manufacturers or OEMs and around them equipment and component manufacturers, systems experts such as module and pack manufacturers, as well as materials suppliers and other, related companies.

What sets this sector apart is its roster of players that have quickly established a cluster in Asia and expanded their market positions. Incumbent firms that trace their origin back to consumer electronics dominate, led by Chinese CATL (191 GWh installed in 2023), BYD (70GWh), SVOLT (78 GWh), CALB (20 GWh), Gotion High-Tech (14 GWh), Sunwoda Electronic (9.2 GWh), and Korean brands SK Innovation (120 GWh), Samsung (80 GWh), LG Energy Solutions (300 GWh) as well as Japan's Panasonic (50 GWh).^{1,2} The ten largest battery producers with critical parts of the battery value chain are concentrated in just three countries: China, South Korea, and Japan.



While several hundred companies have announced plans to build battery factories, we expect consolidation and that only a few viable players will succeed. The main criteria to survive will be: access to capital, competitive product and manufacturing technology as well as long-term safeguarding of sales volumes. With regard to capital, more than € 10 billion will be necessary to reach competitive scale and to ensure vertical integration. As for product and manufacturing technology, we are already seeing that the players lagging in this dimension have very poor operating margins, as they need to reach higher volumes to benefit from scale effects leading to lower, more competitive prices for equipment and batteries.

The ten global leaders in battery cell production have all announced plans to build gigafactories, with another 100 followers and new entrants also planning similarly large plants. Rounding out the new ecosystem are another 100 players that want to construct smaller “megafactories” for niche applications.

This ambitious expansion with more than 200 gigafactories in the works provides opportunities for equipment manufacturers to work with two groups of large-scale battery producers: the ten global leaders, and the followers that are trying to catch up and are searching for new partners. This decade, a more than € 300 billion market beckons equipment manufacturers with battery cell OEMs at their core. European equipment manufacturers bring relevant competencies, know-how, capacities, and a stellar international reputation to the table, but currently have only an 8 % global market share. Unlocking a new growth opportunity that includes machinery for module and pack assembly can get them to 20 % or more by the end of this decade.

The time to act is now. Comparing the evolution of the automotive, semiconductor, and newly arising battery cluster offers valuable insights of what's at stake. Europe boasts a strong automotive cluster comprised of a core of OEMs plus their suppliers and equipment manufacturers, all focused on

producing vehicles with traditional internal combustion engines. In Germany alone, one in five jobs depends on this cluster. Going forward, however, automotive competitiveness hinges on mastering digitalization and the performance of battery electric vehicles (BEVs).

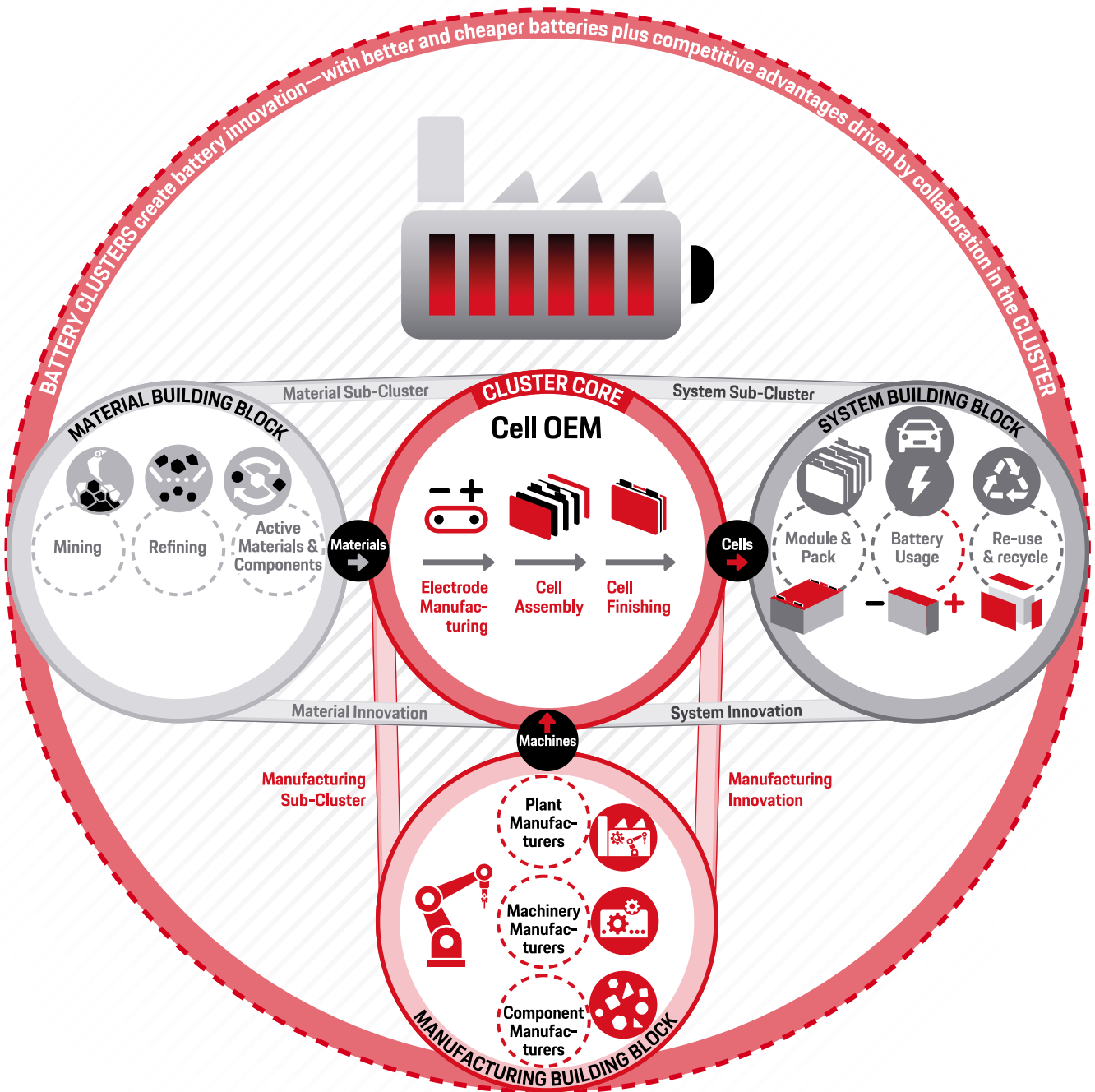
To build a successful new battery cluster means laying the groundwork now to enter a tough race that requires focus, resources, and determination before it's too late.

The burning question is this: How can Europe and North America ride this wave of breakneck growth and successfully establish a second battery cluster outside of China?



Battery clusters drive innovation

The Asian cluster exists—will we see a second European and North American cluster?



© Porsche Consulting

Fig. 2. The battery cluster and its building blocks: innovation and competitiveness driven by the flywheel effect of the cluster.



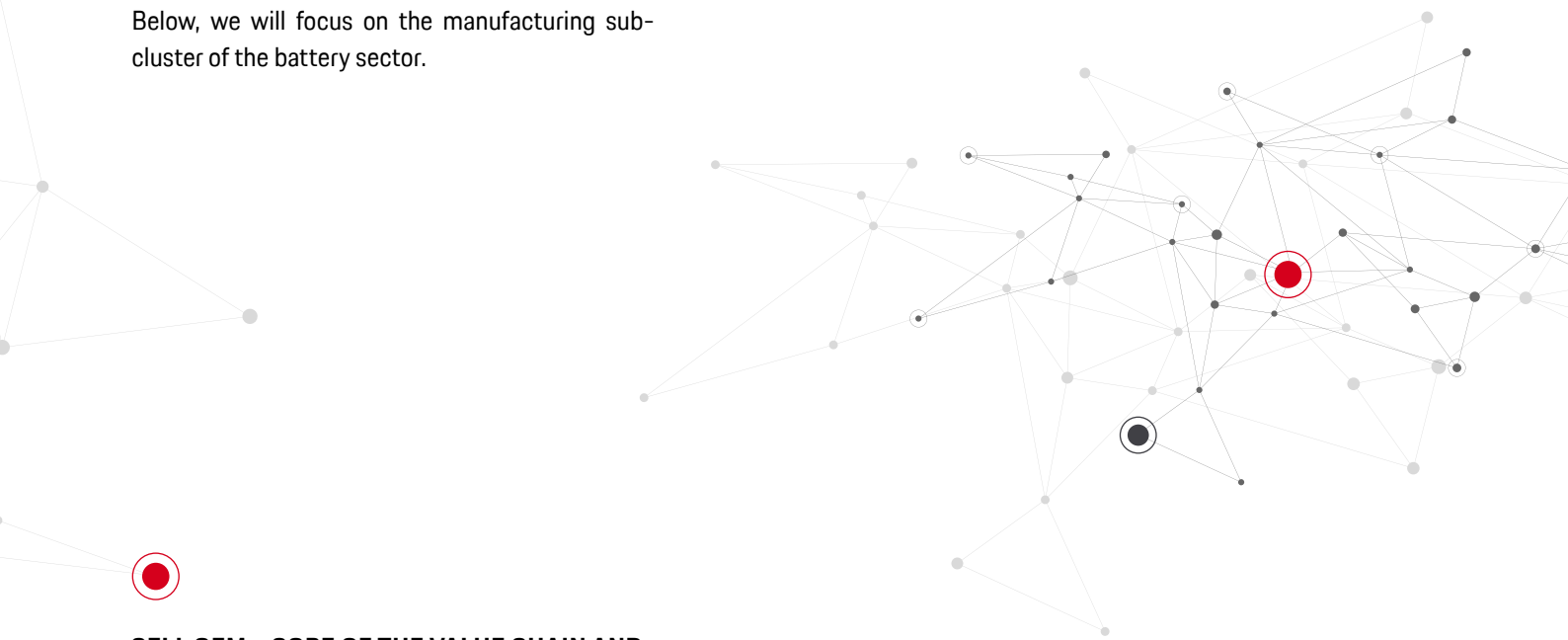
THE BATTERY SECTOR'S STRATEGIC VALUE CHAIN

02

The battery sector's strategic value chain

Technological sovereignty means mastering all steps of the value chain, from extracting raw materials to manufacturing batteries and reusing or recycling them, involving cell OEMs, equipment manufacturers, and other players that make up the building blocks of the battery cluster.

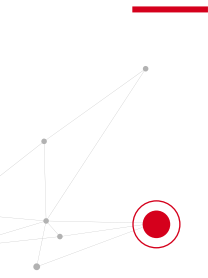
Below, we will focus on the manufacturing sub-cluster of the battery sector.



CELL OEM—CORE OF THE VALUE CHAIN AND OF THE CLUSTER

Battery cell manufacturing is the most important part of this value chain and sits at the core of the new cluster. It requires the interplay between the cell OEM and several value chains: the manufacturing block with equipment manufacturers providing the necessary machinery; the materials chain including mining, refining, and active materials as the batteries' secret sauce; and other related industries and service providers to round out the battery system chain. A gigafactory is an expression of this collaboration: a giga-sized assemblage of machinery producing cells, modules and packs on multiple lines, usually reaching an annual capacity of 30–40 GWh p.a.

Cell manufacturing consists of many processes clustered in three blocks: electrode manufacturing, cell assembly, and cell finishing. Taken together, we expect cell manufacturing to generate accumulated revenues of € 445 billion by 2030 and create a total of 350,000 new jobs. The rapid and steep growth in cell manufacturing will require equipment investments totaling € 220 billion in the gigafactories and another € 80 billion for module and pack assembly in the system building block.



MANUFACTURING BUILDING BLOCK

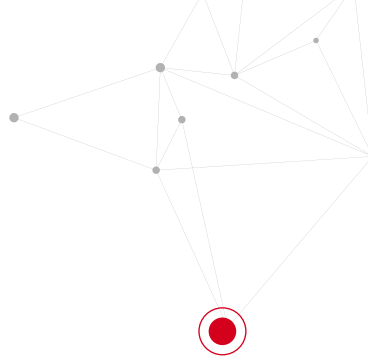
Cell manufacturing varies slightly depending on battery chemistry, but generally consists of several distinct steps, starting with mixing active materials to create a slurry. This slurry is then coated onto a collector foil and dried. Once the dried electrodes are compacted and cut, cells are assembled, tested, and graded before they are finally assembled into battery packs for BEV manufacturers and providers of stationary energy storage systems.

Manufacturing is where the magic happens. Continuous battery material improvements and incremental innovation in process engineering require close cooperation between the cell OEM and the equipment manufacturer. Linking process steps together, for instance, will yield higher quality and output, reducing scrap.



MATERIAL BUILDING BLOCK

The magic of battery cell manufacturing is preceded by materials: mining, refining, and producing the components and active materials, none of which will be the focus of this report. By 2030, we estimate battery-related mining to reach a market size of € 50 billion; refining to be worth € 70 billion; and components another € 150 billion.



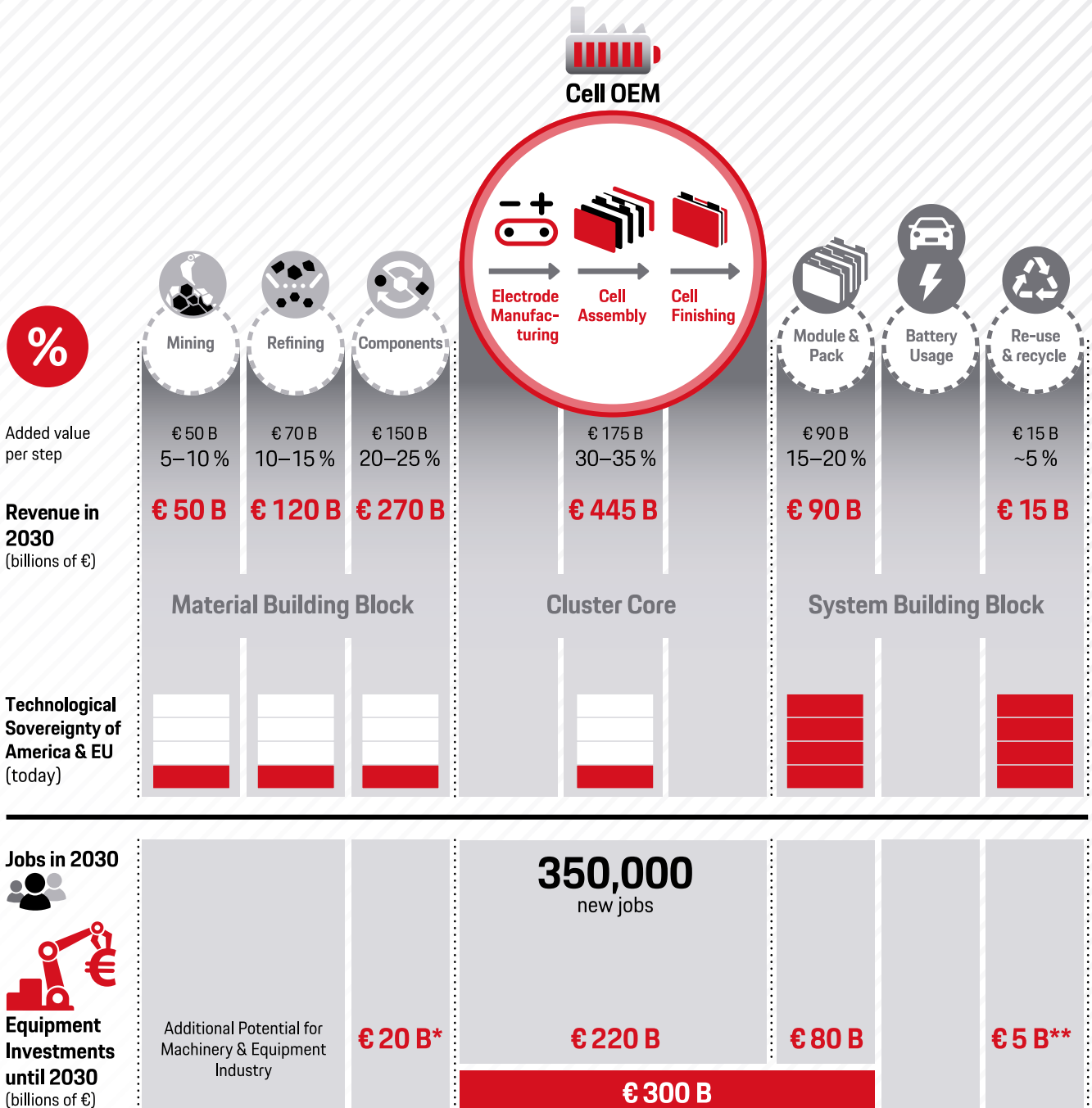
SYSTEM BUILDING BLOCK: BRINGING EVERYTHING TOGETHER

At the other end of the battery value chain is the system sub-cluster, comprised of module and pack producers, customization for the automotive and energy sectors, and the re-use and recycling of batteries—turning battery cells into innovative energy systems. According to our calculations, module and packs will reach a market size of € 90 billion by 2030—with cumulative equipment investments totaling € 80 billion by the same year. Finally, the emerging field of battery re-use and recycling will be worth an estimated € 15 billion. For more details, please refer to the Porsche Consulting white paper on “The Battery Life Cycle”³ and the report “Recycling of Lithium-Ion Batteries,”⁴ published by VDMA and PEM at RWTH Aachen.

A cluster is more than the sum of its parts. Bringing together players from cell OEMs and equipment manufacturers to materials and systems companies creates a flywheel effect benefiting each building block and the cluster as a whole, resulting in economies of scale and increased competitiveness. Given its overall projected size and dizzying growth, the core battery cell cluster presents equipment manufacturers with a unique opportunity. Moreover, if Europe and North America wish to gain and retain technological sovereignty in batteries, it is imperative to master all parts of the value chain and establish a circular battery economy.

Value chain of new battery sector

The battery sector's strategic value chain with revenue opportunities of € 550B (numbers rounded)



© Porsche Consulting

Fig. 3. The battery sector's strategic value chain with revenue opportunities of ~€ 550 B (numbers rounded).

* Cathode active material only

** All machines needed along the recycling value chain from battery collection to disassembly and black mass recycling; for more information, see Porsche Consulting White Paper—Battery Life Cycle



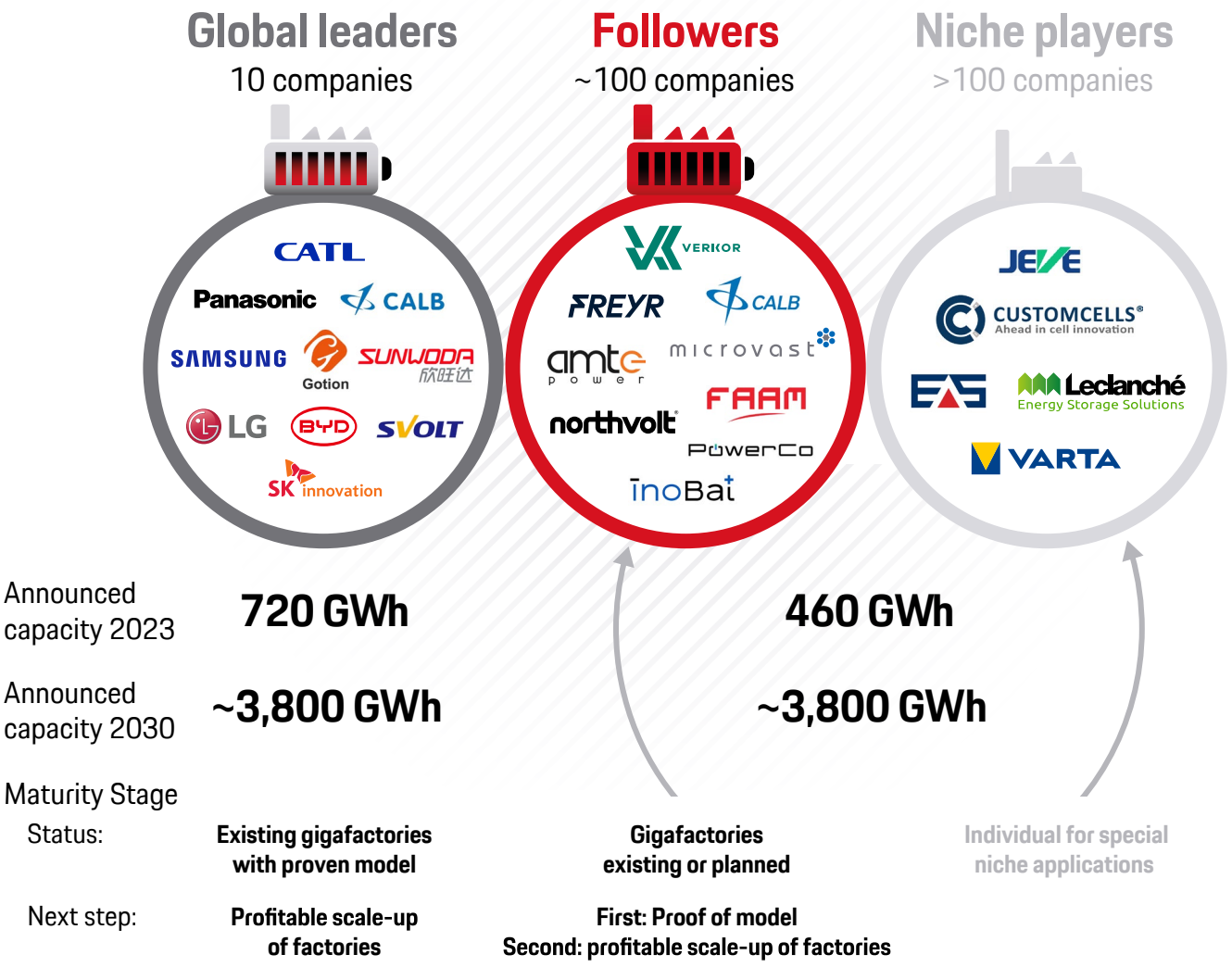
SIX WAVES: from a local to a global sector

03

Six waves: from a local to a global sector

The battery sector in 2024 is still highly localized, mainly clustered in China, with large local companies expanding rapidly to build a dominant global position. European and North American cell and equipment manufacturers nevertheless stand a good chance of working together and establishing a second, globally relevant cluster if they can muster the will and the resources to achieve a dizzying CAGR of at least 50% through the end of the decade.

Currently, battery factories are being constructed around the world, following market demand and favorable economic local conditions. In North America and Europe combined, capacities of up to 3,800 GWh will be installed by leaders; another 3,800 GWh will be installed by followers until 2030.



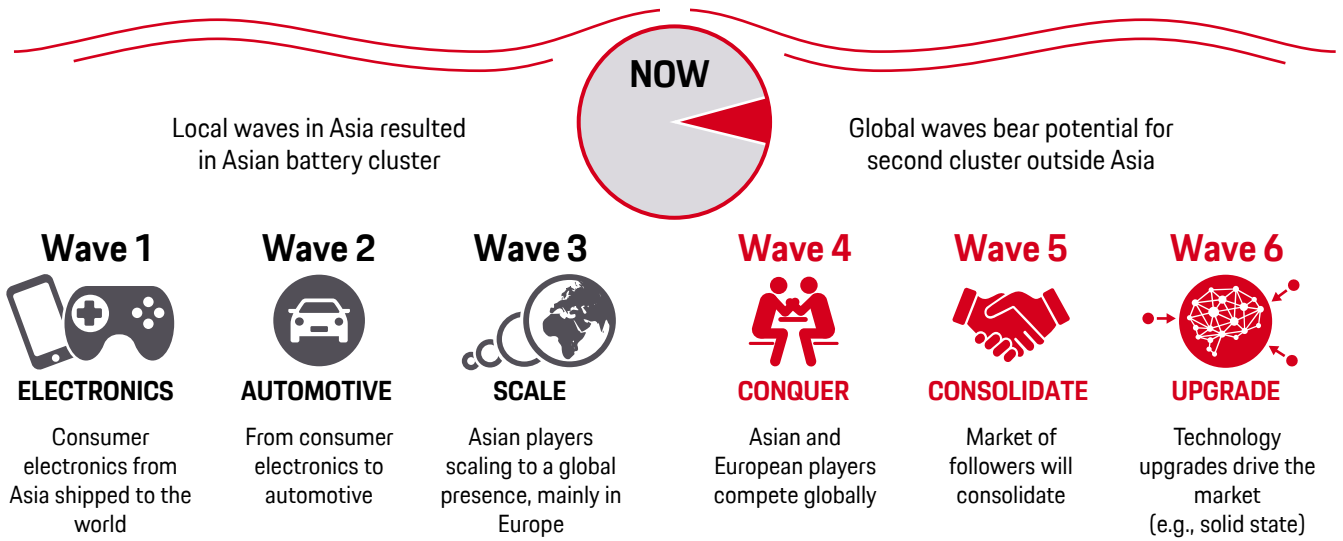
© Porsche Consulting

Fig. 4. The players: Cell OEMs to partner with (indicative numbers based on announcements).

The expansion of battery cell production capacity is unfolding in six waves. The **first wave** was a strictly local affair, with Asian consumer electronics distributed to a global market. **Wave 2** saw the shift from consumer electronics to automotive

applications in Asia for Asia—with individual exceptions such as Panasonic for Tesla in Nevada, USA. The **third wave** was for the first time international, shaped by established Asian players scaling to a global presence, mainly in Europe. During that

Six waves: from a local to a global sector



More than 200 new factories will go online by 2030

Based on announcements and global battery demand (indicative numbers)

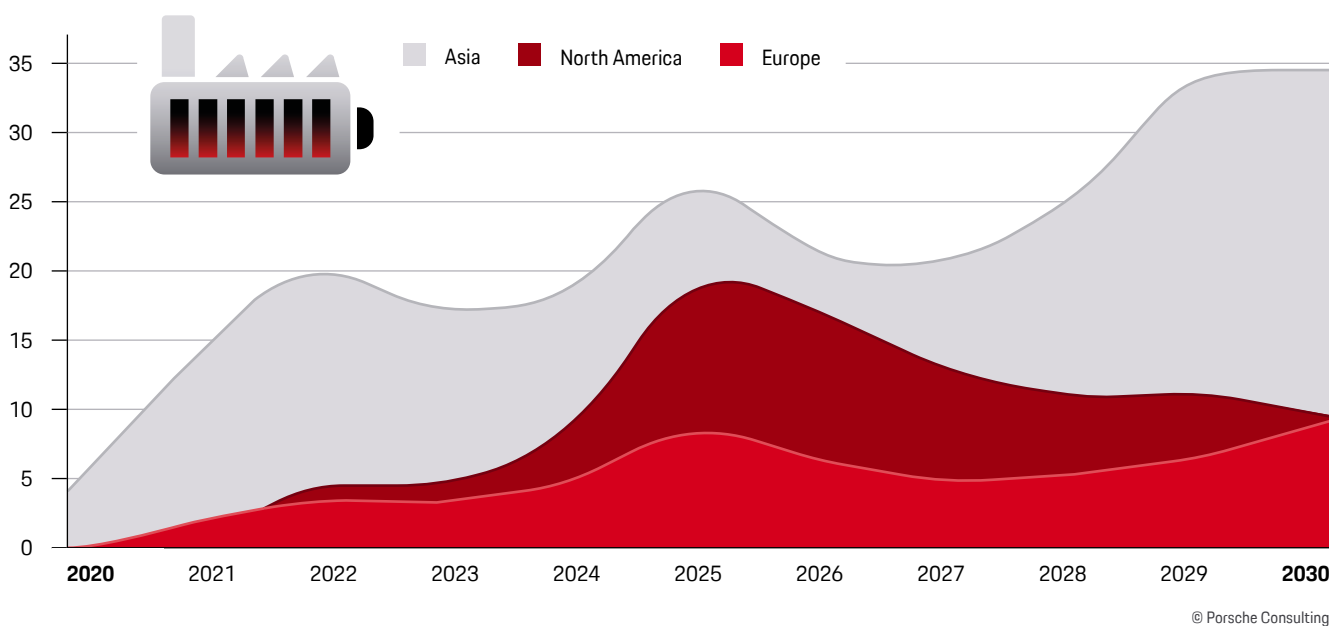



Fig. 5. The time is now: The expansion of battery cell production capacity in six waves.



initial stage, global equipment investments totaled approximately € 50 billion, with 74 % of that sum being invested in Asia, 19 % in the EU and UK, and the remaining 7 % in the U.S. and Canada. Waves 1 through 3, therefore, were dominated by Asian players and let an Asian battery cluster emerge.

Considerably more is at stake now that we are about to enter **wave 4**, where Asian and European players—both cell OEMs and equipment manufacturers—are competing on a global scale. This phase will see a larger total of investments as well as a significant shift in where battery factories are built. Global equipment investments will increase to approx. € 60–70 billion, with Europe and North America receiving around 80 % of this sum, with the remaining 20 % going to Asia. This shifting focus on Europe and North America opens a window of opportunity for local players to enter the game.

During **wave 5**, we expect the market of followers to consolidate as more and more entrants rush into the market. This phase will be shaped by a massive ramp-up in overall investments to boost capacity and efficiency, totaling approx. € 100–110 billion. Asia will regain speed, while investments in Europe and North America will slow down. A focus on technology upgrades and innovation instead of capacity build-up will be the defining feature of **wave 6** in 2030 and beyond, allowing equipment manufacturers to pitch their expertise and know-how in advanced battery cell production.⁵


North America will see its share rise from 5 % to 20 %, Europe from 11 % to 25 %, while Asia's global share will decrease from 84 % to 55 %.



As a result, the overall market share of battery production will significantly shift between continents between now and 2030.

WHERE WILL GROWTH HAPPEN?

While all three geographies will have relevant battery cell production in 2030, the crucial question is where in the world the strongest growth will occur and what it means for the competitive position of Europe and North America compared to Asia? The growth of production capacity is driven by the interplay of regulations and cell manufacturers' localization strategies and other framework costs such as energy costs. Industrial policy in the form of subsidies and tariffs plays a role, as do access to raw materials and low factor costs that affect cell OEMs, equipment manufacturers and other, related players. Taken together, a fluid set of push-and-pull factors will impact decisions about where to locate new battery cell factories in North America, Europe, or Asia.



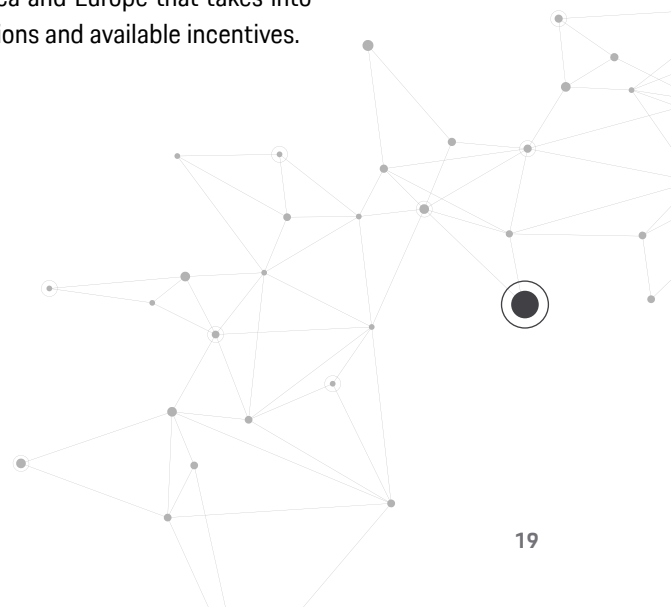
Factor costs in the form of energy and labor as well as access to capital are essential variables in this equation, and they can put European locations at a disadvantage. A new factory with 30–40 GWh p.a. capacity faces additional energy costs of €20 million p.a. if the price per kWh goes up by only one cent.

European and North American efforts to grow their semiconductor cluster into a viable competitor on the global stage hold valuable lessons. This cluster has equipment manufacturer ASML at its core and comprises global players such as Nvidia and Intel in the U.S., complemented by production know-how provided by TSMC in Asia. Governments are employing industrial policies to reduce dependencies and locate semiconductor factories in Europe and North America, including €20 billion in financial incentives. While each cluster has its own framework and therefore calls for different approaches, it is clear that a new battery cluster needs to be nurtured and built to avoid new dependencies in procuring the necessary equipment.

We are now at a crossroads with regard to whether the Asian cluster will succeed in exporting its model to a new location or whether a new, second cluster will arise. The Chinese cluster is facing growth challenges, in particular cell OEMs, around very low margins due to excess capacity. Raising new capital is tied to stringent regulatory requirements, pushing cell OEMs to access fresh funding through their operative business. Expanding overseas is one obvious choice they are pursuing.

In the U.S., the Inflation Reduction Act lures cell OEMs with high incentives of around €35/kWh and per vehicle (€6,930 as of January 2024), which adds up to several billions' worth of subsidies per cell factory. Chinese players, however, are excluded from receiving those incentives. The IRA will therefore prevent Chinese companies from establishing a competitive position in the U.S. market in the coming years, which provides an opportunity for Korean and Japanese incumbents such as LG-Chem, SKI, SamsungSDI, and Panasonic as well as European newcomers such as Northvolt, particularly if they enjoy automotive backing.

We're already seeing Korean manufacturers making forays into the U.S. with large investments and, at times, using incentives provided by their government. All players, including Chinese companies, are pushing into Europe as the second promising overseas market, making a price war highly likely. How, then, can European newcomers stay in the race and grow? By establishing a strong presence in both North America and Europe that takes into account local conditions and available incentives.



A CLOSER LOOK AT THE ASIAN CLUSTER

Given the strength of the Asian cluster, it's worth taking a closer look at the players that invest in and operate battery cell factories. In 2020, incumbent Asian manufacturers from China, Japan, and South Korea were commanding close to 100 % market share. Contemporary Amperex Technology Co. Limited (CATL), headquartered in Fujian Province, is the centerpiece of the Asian cluster with almost one-third of the global battery market. Founded in 2011, it has approximately 33,000 employees and holds more than 2,100 patents on battery chemistries and format.

In 2022, CATL had a market cap of up to € 230 billion and reported € 5.8 billion in EBIT, putting its gross profit margin at around 20 %. One of the key strengths of a large and established player such as CATL is its full vertical integration, ranging from mining raw materials from China to Australia and Argentina, to producing all cell components and manufacturing them in China and Germany. In addition, CATL can rely on Chinese equipment manufacturer Wuxi Lead as a key trusted partner. The cluster's strength is the sum of its building blocks, from materials to manufacturing to the overall system. Asian players are therefore well prepared to leverage their local strengths and expertise to scale up globally. Wuxi Lead has defined the industry standard for manufacturing equipment in Asia, leading cell OEMs to demand backward compatibility for other, seemingly superior solutions in the market.

The massive lead of Asian manufacturers raises intriguing questions about market capture and technological sovereignty going forward. As mentioned above, the dominant players of the battery cell sector are expected to see their market share drop to 55 % by 2030. The initial Asian cluster may be challenged by a second cluster arising in North America and Europe if those players can come together to make a concerted effort.

Europe and North America will be successful, though, if the second battery cluster covers the entire value chain of battery cell production, including materials, systems, and cell manufacturing equipment, with all its building blocks. As detailed above, the race is on. It is defined by Chinese incumbents pursuing an aggressive price policy while facing limits to raising new capital, and by the effects of the Inflation Reduction Act (IRA) in the U.S. Taken together, those factors provide a window of opportunity in Europe and North America but are also likely to increase competitive pressure in Europe.

The initial Asian cluster may be challenged by a second cluster arising in North America and Europe if those players can come together to make a concerted effort.

WHAT IT TAKES TO SUCCEED

Several factors will determine whether equipment manufacturers will play a relevant role in waves 4 and 5, foremost whether they have production capacity, delivery capabilities, and overall experience. Offering a reliable product that corresponds to current industry standards (defined by Asian incumbents) comes first. It also forms the foundation for later overtaking them, based on the considerable know-how and experience many European equipment manufacturers have. How good, in other words, is the product an equipment manufacturer is offering and how competent are they to meet their customers' demands? The second important factor is references. To gain and build trust, manufacturers must be able to point to factories they have already completed. Third, battery cell manufacturers look for turnkey capabilities when choosing equipment manufacturers. Our survey shows that 25% of cell OEMs want complete factories as turnkey solutions, while the remaining 75% are willing to negotiate their procurement needs, for instance purchasing sections or processes. Can a manufacturer either deliver a turnkey product or can their machines be seamlessly integrated into a factory? The existence of a regional cluster is another important factor, as those smaller clusters can drive growth as long as they are large enough to be independently viable.

Size and focus matter, too. Equipment manufacturers need to be able to rise to the challenges of fulfilling large-scale orders, particularly with respect to the financial demands of equipping a sequence of gigafactories. Potential customers will also pay attention to the question whether battery production equipment is a manufacturer's mainstay or just a side business. The crucial challenge lies in cell OEMs collaborating with equipment providers to assure integration of machinery into their processes and to together be ready for the sector's rapid and steep growth (for concrete steps equipment manufacturers can take, see Chapter 06).

The overall economic conditions favor Chinese players, starting with a larger, readily available,

and qualified workforce. Access to funding and bureaucratic hurdles have also not been an issue in China. New obstacles for Chinese cell OEM leaders to raise capital are making it harder for them to expand, while margins in their local markets are going down. For followers in Europe and North America, raising capital for battery projects comes with a higher risk and an uncertain return due to less experience. For the time being, we see the entire battery cluster and equipment manufacturers in Asia in the lead when it comes to technology, references, turnkey capabilities, regional cluster viability as well as size and focus. That still leaves a window of opportunity to create a second cluster, provided all stakeholders can quickly agree on a concerted effort.

Asian manufacturers face additional challenges in terms of making their products scale up and work internationally and often accept a trade-off between global scalability and quality. This includes operating in local languages and standards, as well as meeting demanding OEM specifications for Europe and North America. Asian operators regularly face ramp-up delays of three to twelve months, providing an opening for European and North American competitors.

Europe and North America, by comparison, have a leg up regarding technical know-how and their intellectual property portfolio. They can also point to a superior international footprint and excellent global reputation. On the downside, the two geographies are at a disadvantage when it comes to large-scale references and the lack of turnkey integration.

In sum, Europe and North America need to cooperate closely to complete a tall order of tasks and do so at a rapid pace if they want to compete with and ideally outpace Chinese competitors at their own game.





THE BATTERY MARKET TSUNAMI: how to ride a dizzying growth curve

04

The battery market tsunami: how to ride a dizzying growth curve

Running this race requires getting ready for rapid and dizzying growth. It requires new ways to cooperate and develop a common master plan for 2030. Rising to this challenge calls for working with third parties, including from the public realm.

As Chinese manufacturers race ahead and solidify their lead, European and North American competitors are trying to scale, catch up, and realize their growth opportunities. In order to succeed and secure their share of building and equipping more than 200 new gigafactories in this decade alone, they must compete at unprecedented speed. What, then, are the opportunities and challenges for battery and equipment manufacturers to become involved in time to benefit from the fourth and fifth waves through 2030 and beyond? And what are the right strategies to compete for projects and signing up partners?

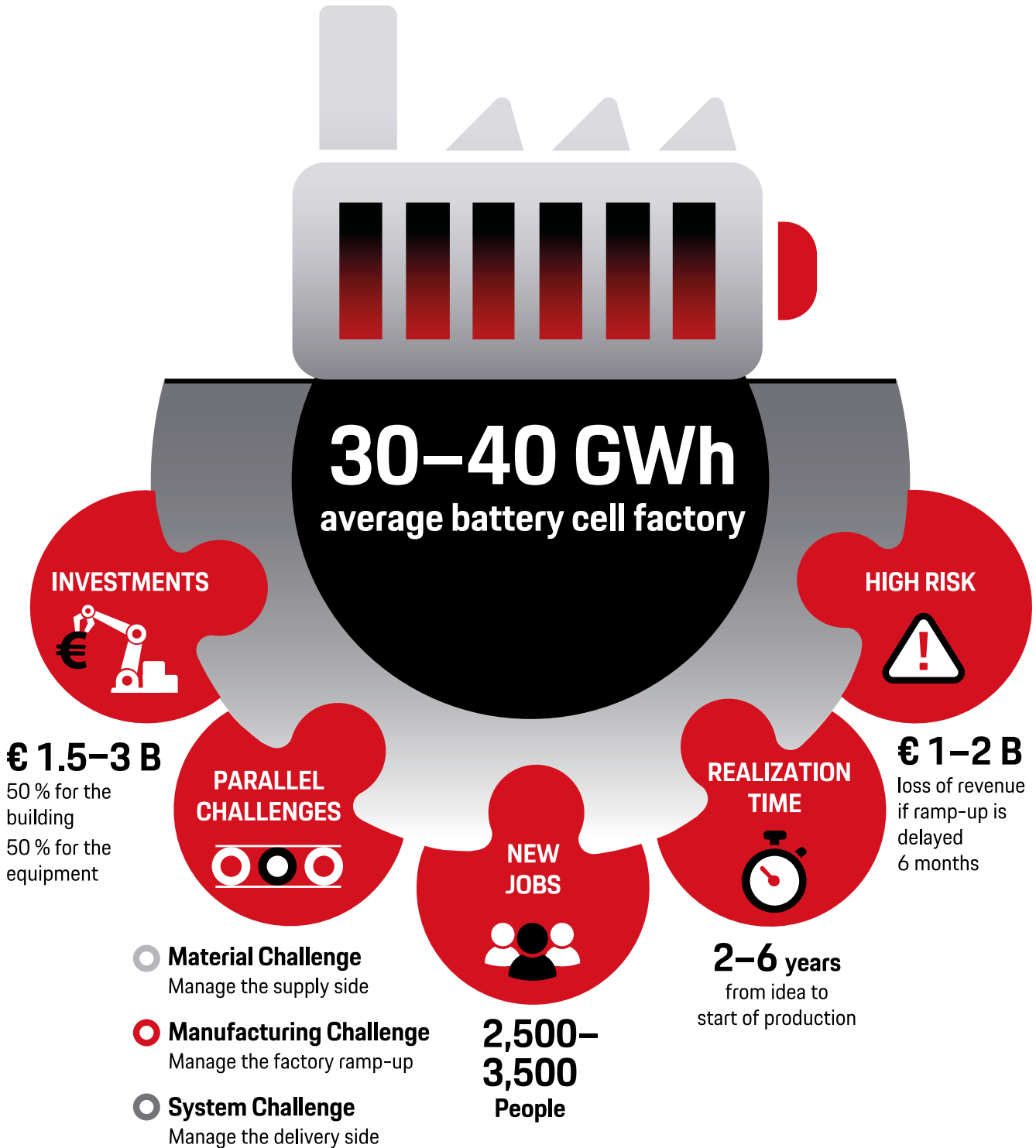
REALITIES OF THE NEW SECTOR

Size matters when it comes to building battery cell factories, of which 65–95 will be located in Europe and North America. Every gigafactory is a giga-scale project across multiple dimensions, including capital expenditures. Since there is a minimum size for a factory below which it is not economically viable, smaller players are generally at a 15–20 % disadvantage in costs per cell compared to large-scale volume manufacturers.

While the average gigafactory has an annual output of 30–40 GWh p.a., plant size varies depending on its individual characteristics. Some players even plan for larger gigafactories with double that capacity or more. Bringing such gigafactories online requires investments of € 1.5–3 billion per 30–40 GWh capacity, divided equally between € 0.75–1.5 billion for machinery and another € 0.75–1.5 billion for buildings and infrastructure. Running a 30–40 GWh factory also requires around 2,500–3,500 employees.

Gigafactory:

More than 200 new factories by 2030



© Porsche Consulting

Fig. 6. Size matters: Every gigafactory is a giga-large CapEx project with multiple challenges (indicative numbers).

Given the enormous scale, a giga-project translates into equally large challenges defined by the time frame, structure, and dimensions of such a factory. It takes between two and six years from idea to start of production.

Delays to this schedule have a massive financial impact, since not reaching the desired ramp-up curve for months or even a year incurs significant lost revenue and is a common occurrence. A six-month delay in ramping up a gigafactory with 20 GWh annual capacity translates into a revenue loss of up to €2 billion, and having a new factory only running at half its projected capacity for half a year will incur a €1 billion loss in revenue.

Successfully running a battery plant does not only mean setting up the infrastructure and equipment. It is rather determined by interconnected challenges facing the three key building blocks of the cluster that are essential for success and make such a task even more challenging. Those three challenges deserve a closer look.



MATERIALS CHALLENGE

First, raw materials such as lithium and other, new, and rare ingredients need to be procured and embedded into a logistics framework to meet desired quantities, locations, and deadlines. Getting battery cell chemistry right and constantly evolving it is a key component for success. All players in the equipment and manufacturing cluster must work together to master the materials challenge.



MANUFACTURING CHALLENGE

Manufacturers also need to manage procurement and installation of the equipment, including the skills challenge of hiring and qualifying a sufficiently large workforce. Once the equipment has arrived on site, they have to make sure that operations for set-up run smoothly, problems are quickly addressed, and overall equipment effectiveness (OEE) is refined along all process steps to ensure that output increases during ramp-up and that battery costs are reduced year by year.



SYSTEM CHALLENGE

The third challenge revolves around innovating the value chain from cell to battery systems to meet application-specific client demands, like charging and energy density. That is particularly true for module and pack production, where specifications and configurations have to meet customer requirements. The delivery and logistics chains need to be managed well to ensure that finished products reach customers. Module and pack is one segment of the cluster where equipment manufacturers have already risen to the challenge and operate as general contractors offering turnkey solutions.


An equipment manufacturer needs strong and reliable suppliers and partners to succeed in this cluster, first of all agreeing on a shared path forward around a common standard. Such is the case with the current Chinese Industrial Standard that forms the foundation of the cooperation between CATL and its production technology provider Wuxi Lead, which was founded in 1999. For fiscal 2022, it reported revenues of € 13.8 billion, representing annual growth rates of up to 72 % with 39 % in 2022, and employs more than 21,000 people in 16 countries and regions. Such established partnerships between cell and equipment manufacturers or between equipment manufacturers, including common standards, do not currently exist in Europe or North America but are essential to eventually outpace Asian competitors. As of now, there are no equipment manufacturers who can play the overarching role of “general contractor” to integrate all process steps, providing a turnkey solution and be the single liaison with a battery cell company. One exemplary exception is the relatively new alliance between the German companies Dürr, Grob, and Manz that demonstrates how things are changing on the equipment manufacturers’ side. The absence of such partnerships points to a classic chicken-and-egg problem, which will become even more pressing as the battery sector experiences a dizzying growth rate.

Integration under the umbrella of a general contractor or systems integrator reduces complexity, makes standardization easier, and is crucial for a successful cluster to emerge, as it enables all players to guarantee synchronization and enable the necessary standardization. Equipment architecture has to be aligned across the entire value chain, from electrode manufacturing and cell assembly to cell finishing, as do availability of the machinery and ramp-up once installed.

Going forward and to make this dizzying growth happen, cell OEM and equipment manufacturers should both aim for a one-stop shop model that lets them respond to all customer needs, although that may run counter to the origins and predominant mindset of the industry. Successfully competing in the battery sector requires different partnerships and new forms of collaboration, both offering new ways to manage the speed of insanity and eventually pass competitors.

Cell manufacturers have to pay attention to a set of basic requirements in order to achieve their desired return on investment (ROI). At the most basic level, the ROI of a large project depends on meeting various milestones: starting the project on time, ramping up according to plan in terms of time horizon and budget, and quickly hitting the agreed-upon levels of output and quality. Leaders in the field usually follow an existing investment model that is simply scaled, but they have to make sure that the business case is a fit for new locations. Followers, for their part, have to back their massive investments in a new factory with convincing arguments and prove ROI, facing off against established competitors such as CATL. The math is unforgiving: if the costs for machinery and buildings increase by 10–20 %, EBIT will be reduced by 1–2 base points.

Technological innovation always plays a role in achieving the desired ROI, for instance by moving from wet to dry coating of electrodes. The type of technology used in cell manufacturing is responsible for 15–30 % of cell costs, which can range from € 60–119 per kWh.

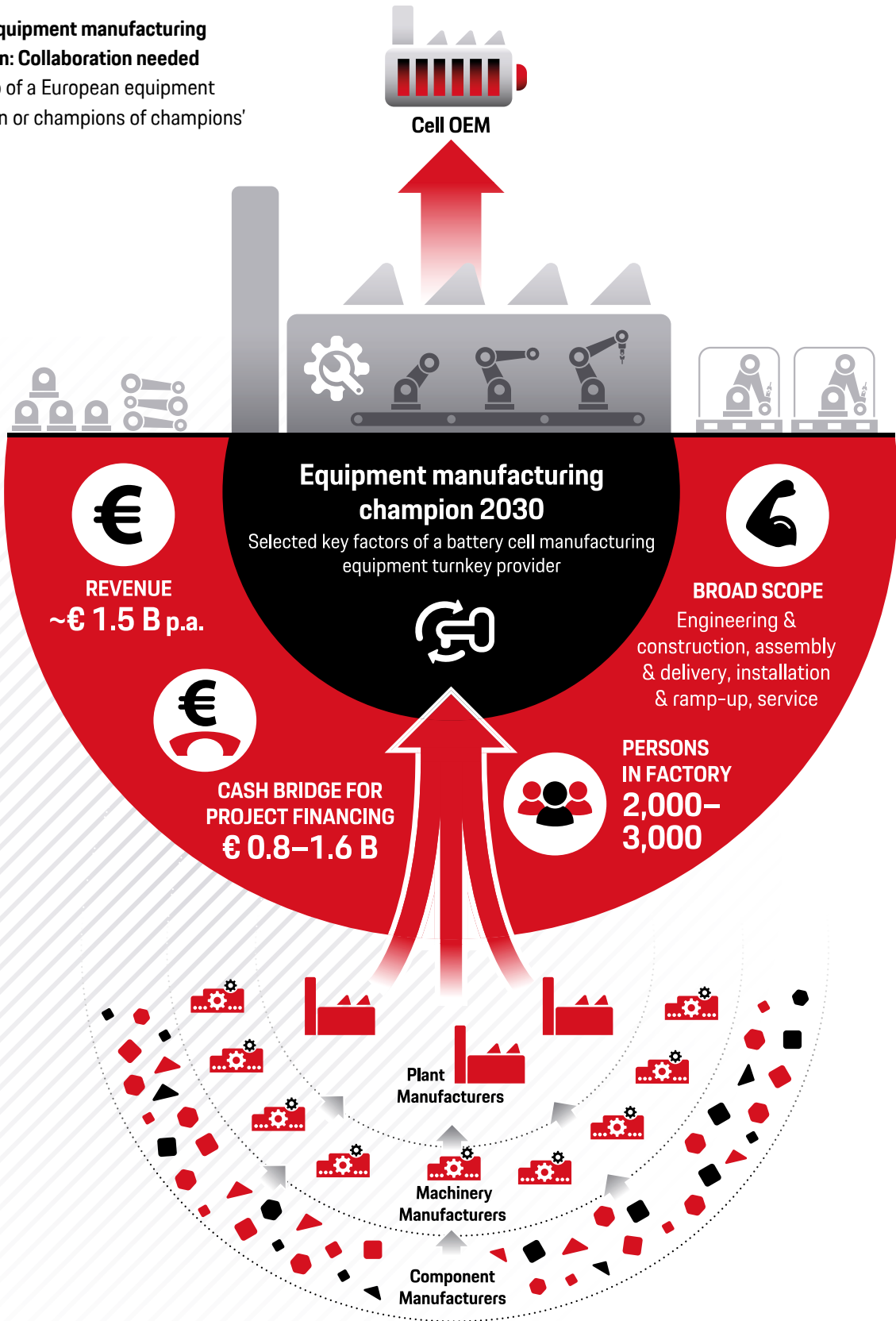


Equipment manufacturers face sizable challenges to grasp the opportunities the quickly rising battery market offers: they need to be very fast and demonstrate competence, be in control of necessary production capacities and have access to the financial resources to handle whiplash growth, as well as demonstrate regional proximity to their cluster partners.

For a future equipment manufacturing champion, it should not be unusual to work on equipping three or more gigafactories simultaneously, given the immense growth of the battery sector through 2030. One plant is in ramp-up mode while machinery for the second one is being produced, and plans are being drawn up for the third. Since cell manufacturers pay for each phase, equipment providers will have to secure interim financing ranging from € 0.8–1.6 billion, depending on the duration of the project, which can range from three to six years. This is to cover the difference in time between cash-out for material and personnel and receiving the down payments from a cell OEM. Due to the currently missing economies of scale and different regulations, project costs in Europe are about 20–50 % higher than in Asia. Local manufacturers are therefore in need of € 1–2 billion in scale-up-financing to grow and emerge—either from investors or public sources. In addition, an equipment “champion,” i.e., a company that acts as general contractor or systems integrator, creates up to 3,000 new jobs, mainly in engineering and construction, assembly and delivery, and ramp-up support. The faster a factory can be completed and brought online, the less capital is necessary, but the more manpower is required.

Bringing factories online on time and on budget is a crucial determinant of success that cell and equipment manufacturers should focus on working together.

Future equipment manufacturing champion: Collaboration needed
 Scale-up of a European equipment champion or champions of champions' network



© Porsche Consulting

Fig. 7. Future battery equipment manufacturing champion.

Over the coming years, close to half of the planned new gigafactories will be erected in Europe and North America, which opens up the chance to build a new battery cluster outside Asia.

The ten leaders in the cell cluster have announced that between 105–130 factories with 30–40 GWh capacity each will be erected until the end of the decade, which translates into about more than one factory a month. Around 20–30 of those will be located in Europe and North America, and the remaining 85–100 in Asia. Only a handful of large followers, mainly backed by automotive investments, have the most concrete plans to build gigafactories as well, planning to build at least one gigafactory every other month. Overall, followers in the cluster plan to build 55–80 factories with 30–40 GWh of capacity, of which 45–65 will be located in Europe and North America and just 10–15 in Asia. Many of those planned factories are announcements that have yet to materialize, but it is very likely that leaders will follow through with their plans compared to followers.

Finally, there is the smaller-scale factory segment with niche players. This segment is dominated by smaller companies with batteries for special applications and characteristics, as well as research factories to experiment with new technologies.

MAJOR OPPORTUNITIES UNTIL 2030

European equipment manufacturers have many opportunities to enter the market in waves 4 and 5, mainly by supplying machinery for gigafactories. Following are five entry scenarios.

01 PARTNER WITH FOLLOWERS

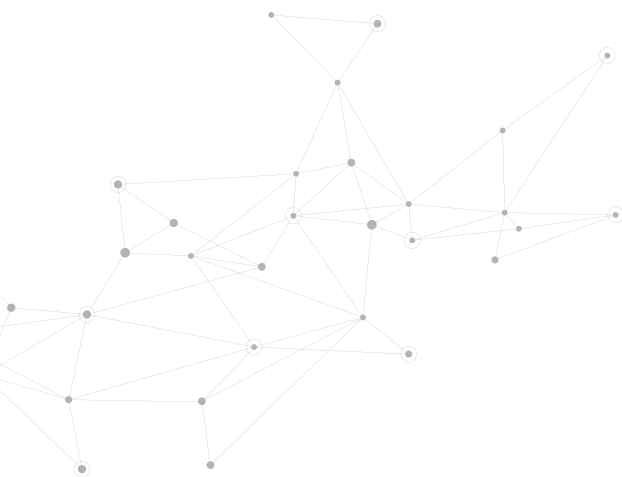
If they aim to compete in the large segment, they can partner with newcomers in the cell manufacturing space. One possible scenario here is a strategic “local for local alliance,” where European and North American players prefer buying their equipment from local companies to build a second cluster.

02 HOPE FOR BOTTLENECKS

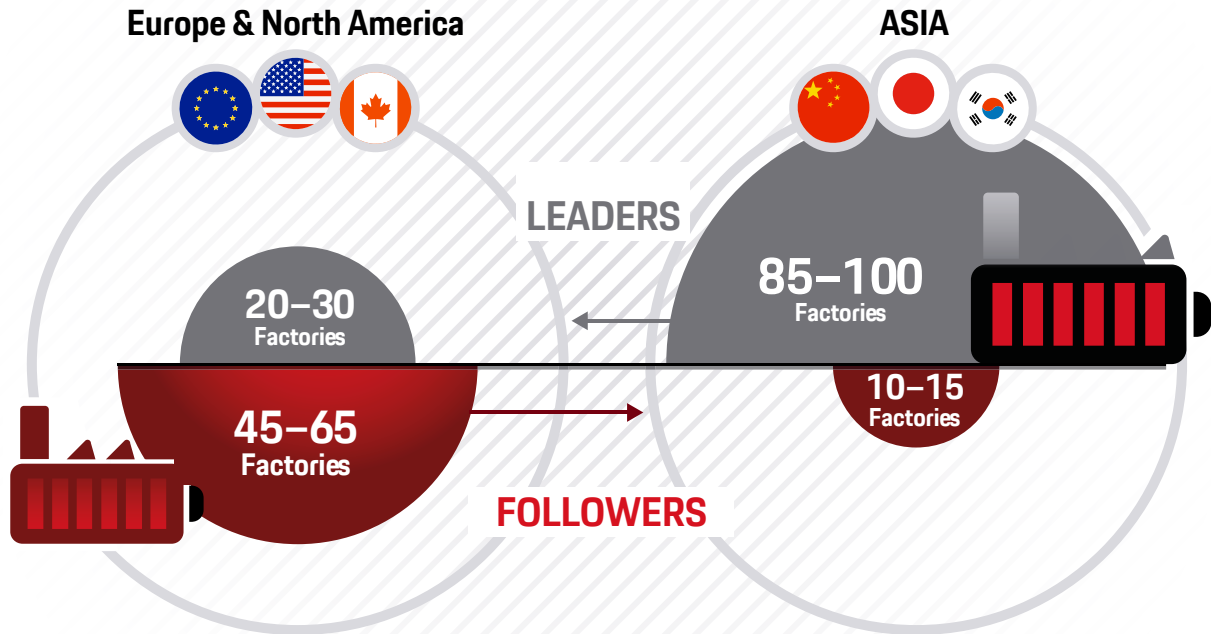
A second “opportunistic scenario” driven by an insane growth rate arises when Asian companies struggle or face capacity bottlenecks and cannot supply all European and North American factories with their machines. It is doubtful, however, if that demand would suffice to let a new cluster emerge.

03 PROTECTIONISM

The third, protectionist option would be to benefit from public policies that either mandate European and North American equipment for European and North American factories or incentivize such purchases to force the creation of a new battery cluster through political means.



Leaders and followers: Investment plans until 2030



© Porsche Consulting

Fig. 8. Business opportunities for equipment manufacturers: Where leaders and followers build factories (indicative numbers).

Opportunities 01 to 03 are predicated on having technologies on offer that are “good enough” compared to Asian competitors. If equipment manufacturers check those boxes in terms of completing such projects on time and on budget, they will increase their chances of partnering with followers as well. By 2030, followers will build an estimated 45–65 factories in Europe and North America with 30–40 GWh capacity each. Supplying those plants will enable equipment manufacturers to eventually scale and grow with those partners.

Equipment manufacturers can also strive to become the suppliers of choice to the global leaders in battery cell production in Europe and North America. This would mean replacing Asian equipment rivals and is therefore not the most likely scenario in the short run, given that they first must catch up to, and then outpace, incumbent providers. Public policy protectionism could be a theoretical ticket to enter this market, as well as achieving technological superiority (such as

dry coating), which would induce large Asian cell manufacturers to choose European suppliers over Asian competitors. This approach poses a significant challenge as it requires mastering breakneck growth, creating large-scale production and delivery capabilities with the associated financing. Lasting partnerships with these global leaders will only develop, though, if equipment manufacturers can prove that they have mastered the art of building a gigafactory. Global leaders have announced plans to build 20–30 such factories in Europe and North America by 2030.





04 NICHE

Below the big league, equipment manufacturers can choose to supply machinery for niche factories in the smaller-scale segment and for research purposes. This market opportunity is too small to build a second cluster outside of Asia. Barring success with large, global players and followers, this path would relegate equipment manufacturers to the role of purely European engineering companies that are highly specialized but not scalable. They would have to focus on customers with specialized needs away from the mass market, offering them complete solutions. This strategy consists of selling highly specialized technology with specific advantages in terms of production and processes, but it means forgoing growth opportunities and market share; due to technological dependencies, a second cluster would not arise.

05 COMPONENT SUPPLIER

Finally, equipment manufacturers can elect to become component suppliers for other players in Asia, Europe and North America. This would afford them the chance to participate in the overall growth of the sector without shouldering sizable capital expenditures of their own and without straying too far from their existing core business. But it would not lead to a second viable and relevant cluster; plus, it carries the risk that intellectual property could be copied by competitors.



DECISION TIME: the criteria for picking an equipment manufacturer

05

Decision time: the criteria for picking an equipment manufacturer

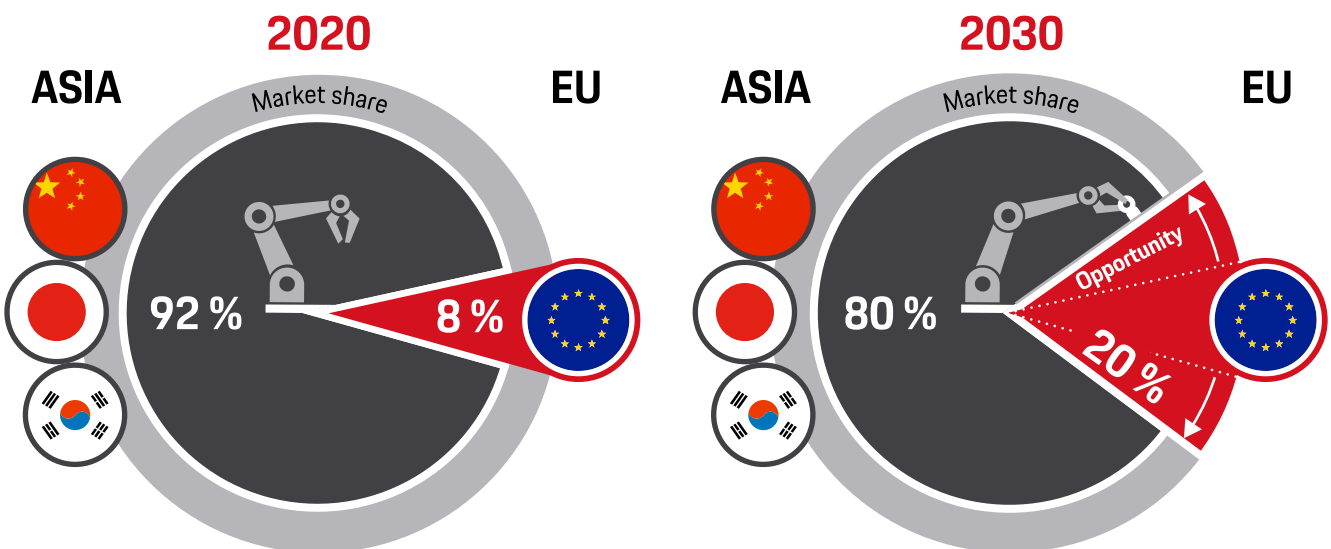
Our latest surveys, conducted together with VDMA, show that equipment manufacturers no longer see the race with China as a lost cause and instead have picked up the pace and are poised to make more gains.

Porsche Consulting regularly takes the pulse of the equipment manufacturing industry. When we polled companies last year, sentiment on the competitive position of Europe and North America was less optimistic than this time around. European equipment manufacturers clearly have an opportunity to work with battery cell manufacturers in Europe and North America. Their global market share currently hovers at a modest 8 %, since Asian

equipment manufacturers supply Asian customers and have begun delivering machinery to factories in Europe as well. When VDMA and Porsche Consulting surveyed 50 executives in the battery ecosystem, including cell OEMs, and conducted an additional validation loop with more than 30 equipment and component manufacturers, respondents expressed confidence that they would be able to increase their market share to 20 %.^{6,7,8}

The Opportunity

Based in our survey, executives in the battery ecosystem see the need and opportunity to shoot for a 20 % market share



© Porsche Consulting

Fig. 9. Market share of European machinery and equipment manufacturing industry.



The assessment is slightly different for the module and pack segment with an expected 50–50 market share split between China vis-à-vis Europe and North America. Manufacturers acknowledged that Asian competitors have successfully provided the bulk of cell production equipment in years past. European companies, by comparison, possess deep experience working with the automotive industry but are still learning how to best meet the demands of the battery cell cluster. The quality label of “European equipment manufacturing” is one of the strengths they can capitalize on when courting cell manufacturers who are looking for alternatives to becoming dependent on an Asian monopoly.


New entrants in the battery cell sector are usually hampered by a lack of knowledge and expertise along the entire value chain, which makes them more dependent on experienced equipment manufacturers, mostly from Asia. They know the process and can offer proven solutions that cover cell production from A to Z. This could create a monopoly situation that makes it unlikely for risk-averse cell manufacturers to engage with new third-party providers to adapt or modify existing factories. Deciders are acutely aware of the dilemma to either keep buying from incumbents and thereby creating monopolies, or looking for alternative options that in many cases first need to be built.

Still, the coming surge of production capacity, particularly in Europe and North America, opens up new opportunities for equipment manufacturers beyond the incumbents. While orders for equipment are currently concentrated in the hands of big players such as Wuxi Lead and others, they will have a hard time to fill all demand for new machinery. Tight deadlines for already announced factories with sizable investments will therefore force cell manufacturers to procure their equipment from new entrants in Europe and North America.

What criteria do battery manufacturers focus on when selecting an equipment partner? The VDMA and Porsche Consulting survey shows that these companies base half of their decision-making process on the type of provider vying for their business and the details of a specific project. Details related to the specific product and type of machinery account for the other half of their decision-making criteria. They take into consideration whether an equipment manufacturer is capable of delivering and scaling as quickly as they are and will be able to be present on at least two continents and have access to sufficient cash. The sector's CAGR of 40% or more, with a new factory going up every two months, creates a daunting trajectory: An outpacing equipment provider doing € 100 million in sales today must be able to scale up to € 2.5 billion by 2030—or risk a newly signed up cell manufacturer switching providers. This scenario is not a theoretical one. As many cell manufacturers are planning to build several plants simultaneously between now and 2030, project overlaps are common. The first plant might already be ramping up while equipment for the second is still being manufactured—two steps that often require the same workforce. Running several battery cell projects in parallel can constrain capacity on the side of equipment manufacturers, meaning companies need to aim for high availability, both in terms of short lead times and volume. Otherwise, they will not be able to furnish equipment for several gigafactories.



An outpacing equipment provider doing € 100 million in sales today must be able to scale up to € 2.5 billion by 2030



In practical terms, equipment manufacturers must be flexible enough to quickly produce and deliver a broad range of modular and scalable products in high volume to keep up with the sector's breakneck growth. A modern gigafactory houses multiple production lines, making supplying them a highly complex task. Equipment manufacturers must therefore have a portfolio of reference projects to prove they can handle such massive engagements.

Such references are key. Cell manufacturers are under pressure to minimize two risks when putting up a new factory. One, they need assurances that their equipment partner has mastered all steps of the production process and is not using a new facility as a test bed to work out possible kinks. Additionally, process technologies have to be mature and proven enough to guarantee operations at mass volume and a fast ramp-up. New entrants in the battery cell are especially dependent on partners that can help them avoid headaches during ramp-up, therefore lowering their exposure to delays and investment risks.


The specifics of the product and machines, including aspects such as purchasing costs, operating expenses, and modularity are the second set of factors that count when selecting an equipment manufacturer. Cell producers focus on total cost of ownership (TCO), which has a direct impact on cell costs and the overall competitiveness of a new plant.

Another decisive factor is the metric of overall equipment effectiveness (OEE), which allows them to compare equipment's full potential to its actual performance. Given the immense capital expenditures required, they have to be sure that their production lines will perform reliably without exceeding their fixed budget for a factory.

In order to make informed decisions, cell manufacturers compare offers from equipment manufacturers in terms of modularity and flexibility. Both criteria are crucial, given that cell size, materials, and chemistry keep evolving, which will require adjusting machinery further down the road. The ongoing development of new battery cells puts a premium on a high degree of modularity, flexibility, and the ability to upgrade. Considering the technological development path and high capital expenditures, the general goal is to use flexible equipment.

Until 2030, a slew of large and capital-intensive projects is on the horizon, as detailed in Chapter 04. European and North American cell manufacturers, whether large or small, have to catch up to the large and established cell manufacturers, as do equipment manufacturers who provide them with the necessary hardware and process expertise. During this decade, the German "Mittelstand's" (small and medium-sized enterprises') traditional ways of doing business will have to confront the realities of global scalability and the expectation to provide turnkey factories (see Chapter 05).

In practical terms, equipment manufacturers must be flexible enough to quickly produce and deliver a broad range of modular and scalable products in high volume to keep up with the sector's breakneck growth.




Equipment manufacturers need to forge new partnerships, both vertical and horizontal ones. Vertical partnerships are alliances between battery cell manufacturers and equipment providers similar to the symbiotic relationships equipment manufacturers have established with automotive OEMs.

Building horizontal partnerships is just as important. Forging alliances between several equipment manufacturers, or cooptation, allows manufacturers to offer turnkey solutions either as a consortium or via partnerships, or by selecting a single turnkey supplier or systems integrator that interfaces with cell manufacturers akin to a general contractor. In the semiconductor space, for instance, Dutch company ASML with its network of suppliers such as Zeiss and Trumpf is a good example of what equipment manufacturers in the battery cell sector could strive for.

European and North American equipment manufacturers with high technical expertise often still exist in the highly specialized world of the Mittelstand, where each company supplies one component for a factory. The way forward looks more like a landscape defined by partnerships and large integrators. Players will be able to develop standards and interfaces that turn smaller, isolated solutions into factory-sized packages of solutions, which make it easier to scale and drive costs down.

A second battery cluster will only emerge if those efforts coalesce. Whether partnerships are forged by economic pressures or by political intervention and substantial incentives, they have the same goal: laying the groundwork for a new cluster where all building blocks are in place and work in sync to rise to the challenge of accomplishing dizzying growth. Beyond vertical and horizontal partnerships to build the business, shaping the system e.g., through private or public investors is important. The latter must happen in a transatlantic fashion, bringing together Europe and the North American Region. Overall, an almost unsolvable task, but worth it.



Equipment manufacturers need to forge new partnerships, both vertical and horizontal ones. Overall, an almost unsolvable task, but worth it.



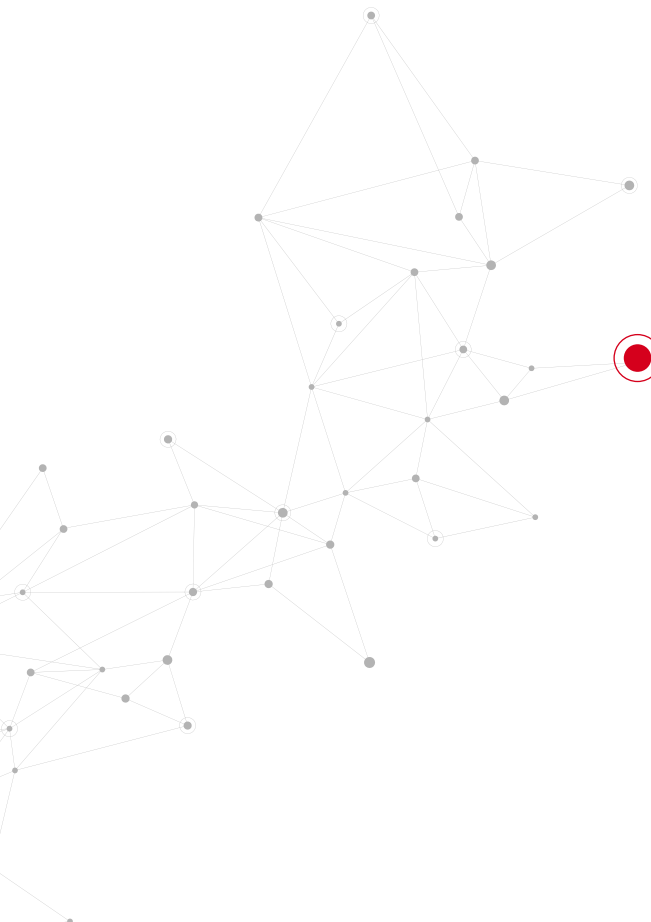
A TO-DO LIST FOR EQUIPMENT MANUFACTURERS

A to-do list for equipment manufacturers


Equipment manufacturers alone will not be able to reach and operate at the breakneck tempo the battery sector demands. They will need to work with cell manufacturers and most likely third parties to help them win the race, embracing first a new mindset and then implementing 5+5 crucial tasks.



Industry and governments need to work together and focus on establishing this crucial sector in Europe and North America now, while there is still time to catch up and eventually outpace Asian incumbents, and generate technological sovereignty. Besides joint efforts that involve private or public entities, every equipment manufacturer has to individually tackle a list comprising a new mindset and 5+5 specific tasks.

Asian manufacturers have a hard time scaling their local success on the international stage. They are also running into headwinds with mergers and acquisitions, as European target companies are often unwilling to sell themselves. In addition, Asian companies face cultural barriers in terms of language, time differences, and sheer geographical distance. A gigafactory or similar large project requires a permanent presence on site or close by, which makes flying staff in or rotating them out challenging and impractical, given how many factories need to be completed by 2030.



What can equipment manufacturers do now to turn those opportunities into reality, growth, and revenues?





First, they must catch up and win reference projects for the second cluster, either in partnership with new entrants to the battery sector or with players outside the core of the Asian cluster. They also have to build partnerships to agree on standards and be able to offer turnkey solutions for new factories, which will only work if and when integration with other manufacturers is assured. Third parties can serve as catalysts for those tasks. Internally, equipment manufacturers have to work on standardizing their own products and interfaces with others in order to scale them quickly and cost-efficiently. Second, they have to pull ahead (details on both steps are spelled out later in this chapter).

The growth of this sector is happening at such speed and such scale, though, that companies alone will be hard-pressed to harness it. One option is for national governments and regulatory bodies to step in and shape the system through industrial policies, thereby most likely increasing chances of success. Their actions would complement industry efforts at building the business, while always giving preference to the free interplay of market forces over incentives or subsidies. Equipment manufacturers can bring a lot of valuable assets and insights to the table. They possess deep and broad technological know-how to design, build, and ramp up machinery; they have proved they can solve complex challenges time and again; and they know how to train the future generations of skilled workers and engineers the new cluster will need.

Economies of scale are essential. European manufacturers working solely with European partners will not be successful, and neither will North American manufacturers working only with domestic partners. A market share of 20% and technological sovereignty will only come within reach and in turn create a second cluster if European and North American players join forces.

Industrial policy ought to put a clear focus on creating clusters as the core of sustainable competitiveness in a global economy. Creating a new

battery cluster affords governments the opportunity to invest beyond basic research, as is too often the case in Europe, or in promoting American-made products, as is the focus of the Inflation Reduction Act in the U.S. If Europe and North America are serious about maintaining their technological sovereignty, they could consider offering assistance to all building blocks of this new cluster beyond equipment manufacturers. Public involvement may well serve as a catalyst for all stakeholders to better assess and manage various risks, ranging from infrastructure and energy costs to the workforce and the bureaucratic and regulatory framework.⁹

To shape the system for a competitive cluster to emerge, some fundamental agreements must be established. They comprise working out a cooperative arrangement between the involved players and establishing technical standards between cell manufacturers and equipment manufacturers to make sure seamless integration toward turnkey solutions can happen. Clusters have historically provided competitive advantages to other industries, such as automotive or rail transportation in cooperation with materials, mechanical engineering, and equipment manufacturing as well as system integration—similar to the cluster logic in the battery sector.

One example for shaping the system are private or public third-party players that will cover the investment risks involved in building a gigafactory, either through interim financing or with a financial guarantee, as is the case with Scandinavian newcomer Northvolt. In China, the government has long been instrumental in forging joint ventures to ensure companies' and thereby the overall cluster's economic viability.

Our calculations show that initial financing of around €2 billion is necessary for an equipment manufacturing cluster to emerge in Europe and North America. Scaling up the cluster would neutralize the cost advantage Asian competitors have and establish competitiveness and in turn attract further investments (private or public).

If companies want to compete in this fast-paced race to achieve a global market share of 20%, they need to be laser-focused on achieving scalability and an unprecedented 50% CAGR. Accomplishing both will help to close the cost gap by realizing scale effects through standardization and productization as well as industrialized production of 20–30%. While catching up and pulling ahead seems to be an almost impossible challenge, there are specific steps every equipment manufacturer can take now to develop a reliable and scalable product, compile references, drive costs down, and keep innovating. They consist of developing a new mindset and implementing 5+5 steps. A master plan establishing clear priorities is key to first get a handle on scaling up and keeping costs in check, and in a second step focusing on achieving technological superiority. Those are general recommendations that need to be adjusted to each company's individual situation.

Given the currently fragmented structure of the equipment manufacturing industry, it likely helps if master players—let's call them "champions 2030"—were to combine all required competencies under one roof and become the one-stop supplier for new battery cell factories, orchestrating a "team of champions" with smaller, hidden equipment champions. Beneath it, smaller companies that do not have the ambition to become a large systems integrator could still cooperate and dominate attractive niches within the new cluster. The situation is slightly different for module and pack suppliers, with a 50% market share split between Asia and Europe plus North America. Here, companies can afford to remain local players. The same applies to component suppliers that focus on a well-defined high-tech segment, as well as small to mid-size equipment manufacturers.

THE MINDSET AND 5+5 STEPS OF OUTPACING COMPETITION

Becoming an equipment manufacturer that can compete with large Asian incumbents requires establishing superiority along the two competitive axes of "scale and cost" and "technological prowess." The race can be won by establishing a superior position in one of those two areas. Yet in light of the dizzying growth and high complexity, a clear focus is needed to outpace the competition. That means it is not advisable to pursue breakneck innovation and scaling up at the same time. Nor is it advisable to chase only one of the two goals at the expense of the other.

Instead, collaboration and a new mindset are needed, focusing on taking concrete steps to catch up and pull ahead in the right order. Equipment manufacturers should therefore prioritize and establish a clear sequence of goals by 2030. They should start with catching up by way of scaling up, matching the current pre-eminent standard given by Chinese incumbents. This approach will help them lower costs thanks to lower technological complexity and highly reliable solutions.

In a second step, they can pull ahead by adding superior technology in a modular approach and establishing their own, advanced standard. This sequence allows them to address their installed base and emphasize their level of expertise. From our perspective, this suggested sequence is also confirmed by the VDMA and Porsche Consulting survey, mainly because cell OEMs want to avoid the risks posed by deploying unproven technology in a capital-intensive environment.

Strategy 2030: The road to success

Possible strategies to catch up, pull ahead and collaborate in the challenging outpacing race

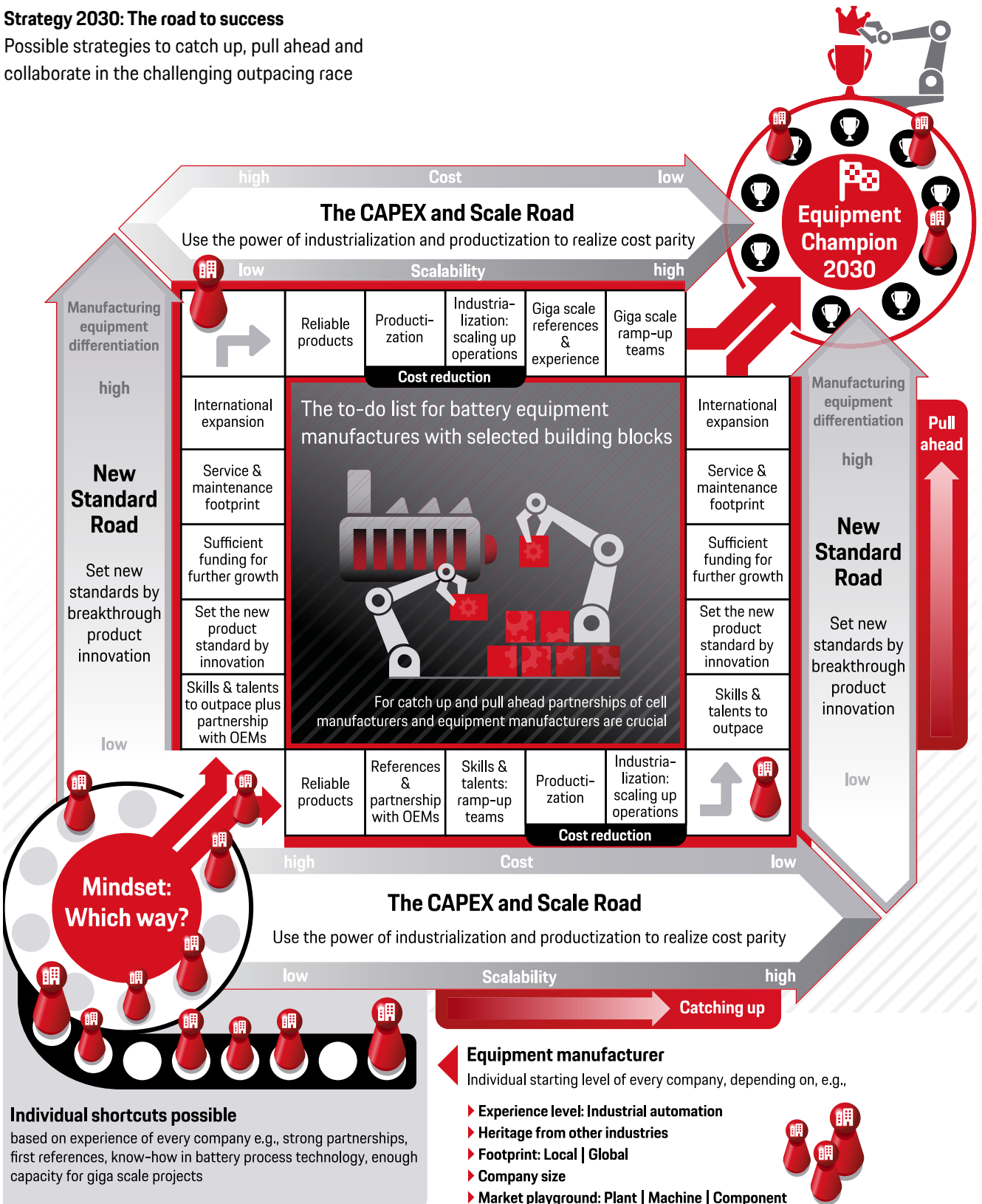


Fig. 10. The outpacing challenge: The to-do list for equipment manufacturers and their partners (e.g., followers).

Instructions for Strategy 2030:

Becoming the Equipment Champion 2030 and advancing to the top right corner is a strategy game that requires companies to find their strengths, playing their cards well and always thinking several moves ahead.

▶ **Taking stock:**

Equipment manufacturers start by first analyzing their strengths and weaknesses such as experience, size, and local or global footprint.

▶ **Moving ahead:**

Leapfrogging the competition also means identifying and taking advantage of shortcuts and leveraging partnerships with other equipment manufacturers and cell OEMs.

▶ **Choosing the right path:**

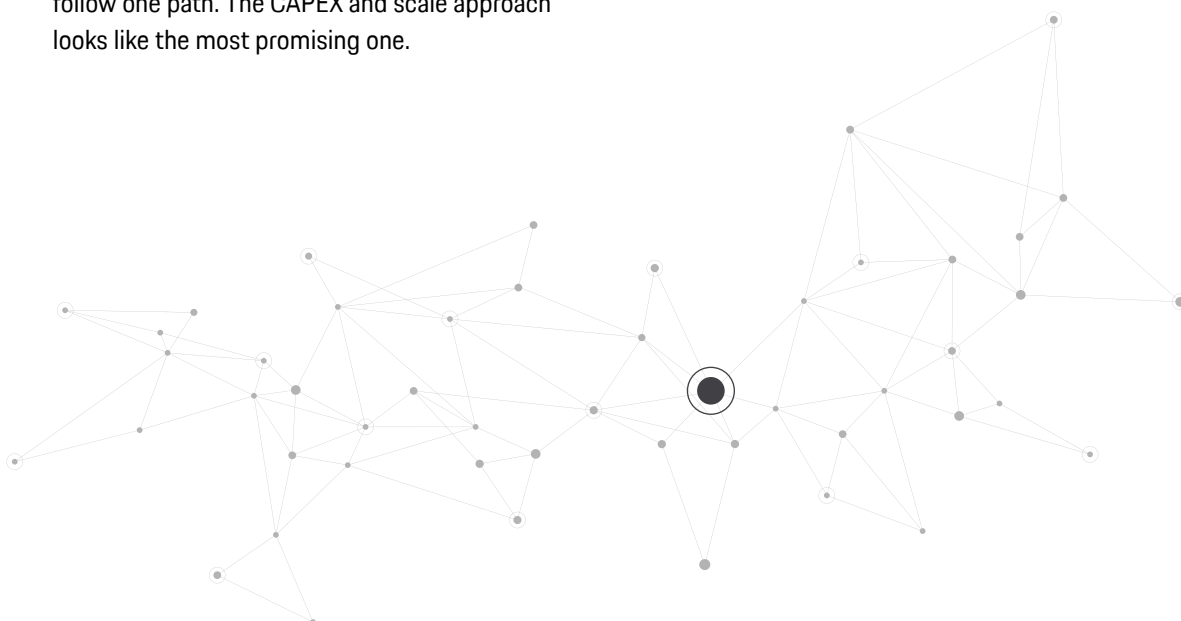
There are two roads to win this race: either by setting new standards through breakthrough innovations or by using the dual powers of standardization and productization to achieve cost parity with Asian companies. Players can only follow one path. The CAPEX and scale approach looks like the most promising one.

▶ **Trust in your strengths:**

While companies make their moves, scale and advance toward the Champion position, they shouldn't forget to use their existing and broad know-how for future product innovation.


▶ **Customized success:**

There is no "one size fits all" approach to win this game. Companies need to define their individual road map with customized building blocks that play to their strengths—from recruiting talent to providing excellent service teams.



MINDSET

The daunting task of breakneck growth calls for a different mindset, based on productization, standardization and scalability. While today's focus is mostly on individual projects, the future hinges on scalability or a focus on standards and modularity that all players can leverage to drive costs down and close the competitive gap to Chinese competitors. The most promising approach to building a new European and North American cluster is to synchronize the efforts and goals of cell OEMs and equipment manufacturers to catch up and eventually pass Asian rivals in the coming decade. Following this path means lower risk, requires less capital, and addresses the concerns of battery manufacturers—and offers in our view the only realistic chance to achieve the needed speed to master such steep growth. It seems unlikely, by contrast, that the industry will be able to achieve such high growth rates by leveraging their usual project-driven and highly customized approach. The shortage of skilled workers is a further argument for following the productization approach.



The preconditions for catching up with Asian manufacturers are scalability and reliable products that will lead to optimized product costs.

THE FIVE BUILDING BLOCKS OF CATCHING UP

The preconditions for catching up with Asian manufacturers are scalability and reliable products that will lead to optimized product costs. The journey starts with the aforementioned productization of reliable, "good enough" offerings. Those are products more on par with Asian equipment, meaning they don't offer a significant technological advantage but keep risks low and simply work as advertised. Being on par in this context does not mean pursuing the same cost profile, which is seen as challenging by many equipment manufacturers, but rather using productization as the stepping stone to eventually outpace the competition. Additionally, "good enough" products need to be modular so they can be quickly and simply adjusted and augmented to pull ahead after successfully catching up. Equipment manufacturers should therefore first focus on designing to cost and designing for manufacturing to ensure maximum scalability with their partners.

The next step consists of securing good references to gain a foothold in the market with their "good enough" offering. This can be accomplished, for instance, through partnering with an established cell manufacturer in a smaller niche, or smaller Asian players outside of China (e.g., Korea), to gather expertise and build a portfolio of successful implementations.

Third are investments in aspects that are highly relevant for cell manufacturers such as ramp-up teams that provide support for getting a new factory online (see Chapter 05). Often, those details can make the difference in landing a contract for a cell project. Those teams should be regional, flexible, and nimble, making sure that a cell manufacturer can indeed ramp up operations and has a dedicated set of eyes and ears to ensure the new factory hits its output targets.

The fourth step consists of achieving competitive costs at minus 20–40% by productization, standardization, and scaling, which is a pre-condition

to outpace China's blazing speed. Equipment manufacturers need to transform their business and processes to move from building and selling stand-alone products to massively scalable products at volume, which would be a break from traditional, project-focused and highly customized work. They can achieve this by standardizing as many of their products and processes as possible. At the same time, they have to build a professional organization that enables them to standardize process steps and make them independent of individual employees or managers.

Scaling up operations is the fifth step. Once manufacturing is set up in a modular fashion, capacity can be ramped up in a flexible way to satisfy demand from battery cell manufacturers. This must go hand in hand with scaling up the supply chain, making sure the supplier base is broad enough to avoid any bottlenecks.

THE FIVE BUILDING BLOCKS TO PULL AHEAD

After catching up to competitors, the goal of eventually outpacing them comes into sight. The basic requirements are scalability, product optimized for cost, and technological superiority. Equipment manufacturers already have the expertise to introduce new processes and keep improving them as growth picks up.

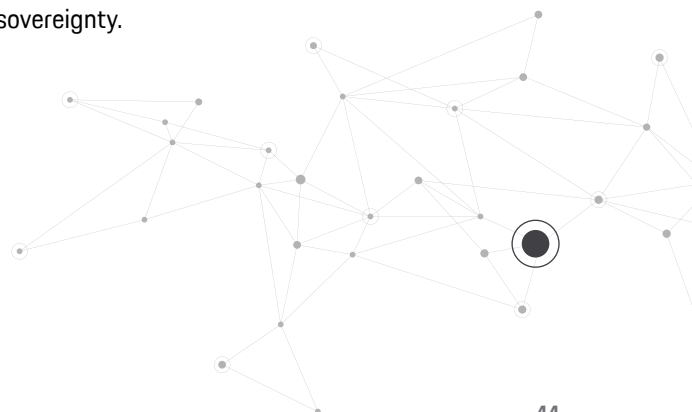
The sixth step along this path consists of constantly expanding skills and the available talent pool. Thus, companies have to invest in strategic workforce planning and prepare for massive recruitment in their core areas of expertise. Establishing standards among manufacturers is a vital precondition to close the skills gap. The seventh step along this path consists of ongoing innovation and development of superior technologies. Pursuing development in-house can be realized and accelerated via "learning in the cluster," which will generate the classic flywheel effect through ongoing and intensified cooperation of cell OEMs and manufacturers, competition, and experience. If these innovations are based on existing, modular


products that are already on the market, equipment manufacturers can ensure they will be able to deliver innovative solutions on an ongoing basis. Generating and appropriately protecting intellectual property will allow European and North American equipment manufacturers to guard their market shares.

Continued growth calls for constantly expanding skills and the available talent pool. Thus, companies have to invest in strategic workforce planning and prepare for massive recruitment in their core areas of expertise. Establishing standards among manufacturers is a vital precondition to close the skills gap.

Steps eight and nine to build a lead in the battery sector are securing financing for further growth and expanding service and maintenance capabilities. What started out as regional and flexible service teams to ensure smooth ramp-up needs to be augmented by global offerings for service and maintenance. Superior service will help protect an equipment manufacturer's reputation and standing with cell factory operators. When all those tasks are addressed, the final step consists of establishing a truly international footprint and, thanks to a global presence, building a worldwide customer base.

At this point, we are fully aware of what investing in and striving to reach these 5+5 building blocks means for companies in this space. We are also conscious of the ongoing discussions whether growth in the battery sector will continue beyond 2030. Yet we are confident that the sector will remain important, along with significant investments in equipment. Both expectations clearly justify any investment made today in future competitiveness and technological sovereignty.





HOW TO GET FROM
8 % TO 20 % OR
BEYOND:
**possible market share
scenarios**

07

How to get from 8 % to 20 % or beyond: possible market share scenarios

The hunt for growth opportunities is what drives economies forward. The booming battery sector presents a rare, once-in-a-lifetime chance to channel astounding growth, thereby creating new wealth and technological sovereignty, plus establishing a sustainable competitive position on the global stage.

The following scenarios are modeling exercises meant to illustrate both the dramatic growth and the tasks facing equipment manufacturers. As our calculations show, growing at the speed of China and eventually outpacing Asian rivals is part and parcel of the ongoing transformation of the energy and mobility sector. The following calculations are

based on projected market demand and are intended to only give ranges rather than precise numbers. Actual market shares will always depend on how the other building blocks of the cluster evolve, impacted by factors such supply of materials and BEV demand. Recent history shows that large projects can be delayed by years or canceled altogether,

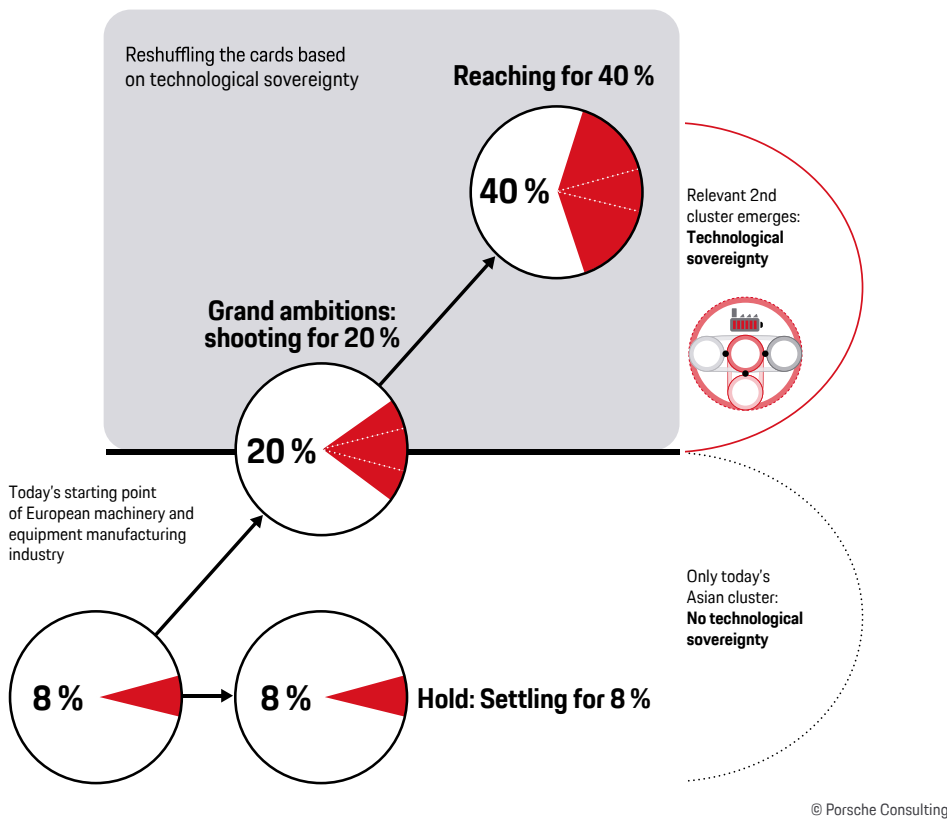


Fig. 11. Emergence of a second battery cluster depending on market share scenarios from 8 % to 20 % or beyond.

while announcements for additional factories are sure to come. Even then, the growth of the battery sector will not slow down and will eclipse the rise of the semiconductor sector.

There are several possible scenarios for equipment manufacturers to make their mark in the sector by the end of the decade, assuming they work in partnership with cell OEMs and other companies in the battery sector. They can simply try to defend their current market share or rise to the opportunity and expand it. Our survey shows that European and North American cell OEMs and equipment manufacturers see an opportunity to grow their footprint from currently 8 % of the global battery market to at least 20 % by 2030, if they can master stunning growth of 50 % CAGR or more.

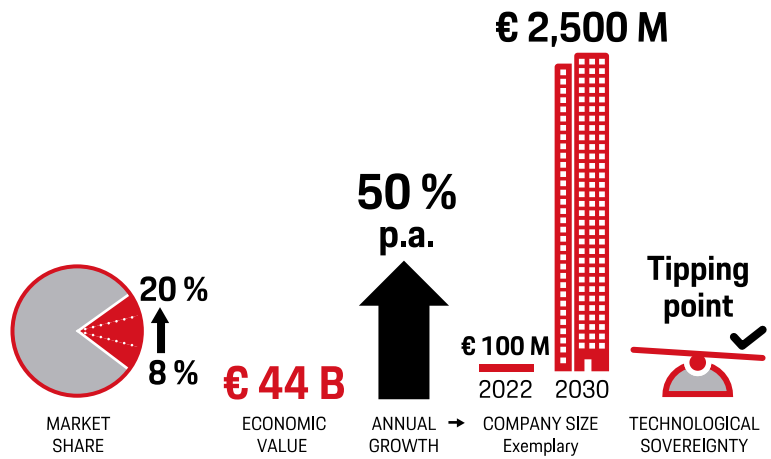
A relevant new cluster comprising battery OEMs, equipment providers, and other industry partners will only emerge, however, if equipment makers manage to reach 20 % share or more. We consider 20 % global share an important threshold. It constitutes a tipping point beyond which a viable cluster can emerge that affords technological sovereignty and thereby less dependence from Asian manufacturers. Failing that, Europe and North America would be condemned to accept Asian dominance, akin to what has happened in the solar panel sector.

SCENARIO A

Grand ambitions: shooting for 20 %

There are several pathways to achieve the 20 % market share that equipment manufacturers themselves deem possible. Yet it requires a relentless CAGR of 50 % through the end of decade. To put this dizzying growth requirement into perspective, it would see a company with currently €100 million in revenues to become a multi-billion-euro business by the end of the decade. The purely theoretical impact of these numbers is already shocking for most businesses—and makes it necessary to rethink their strategy now. If a local cluster emerges that is both regionally strong and less dependent

Simulation of 20 % market share in 2030
Key figures based on model calculation.



© Porsche Consulting

Fig. 12. Scenario: Grand ambitions: shooting for 20 % in 2030.

on Asian players, Europe and North America will be able to maintain their technological sovereignty in battery manufacturing. If, on the other hand, Europe and North America merely manage to fill in the gaps that Asian competitors have left due to their lackluster internationalization, it is unlikely that a second cluster of strategic importance will emerge outside of Asia.

Assuming a strategic, regional cooperation of European and North American cell OEMs with the local equipment industry, the 20 % scenario can become reality, as 45 % of battery cell followers would buy their gigafactory equipment only from local manufacturers. A new cluster would therefore be more regional. Equipment manufacturers would, however, only have around 5 % market share in Asia. The result of this strategic cooperation would be 20 % global market share, technological sovereignty, dramatic growth of 50 %, and an economic value of €44 billion by 2030.

SCENARIO B

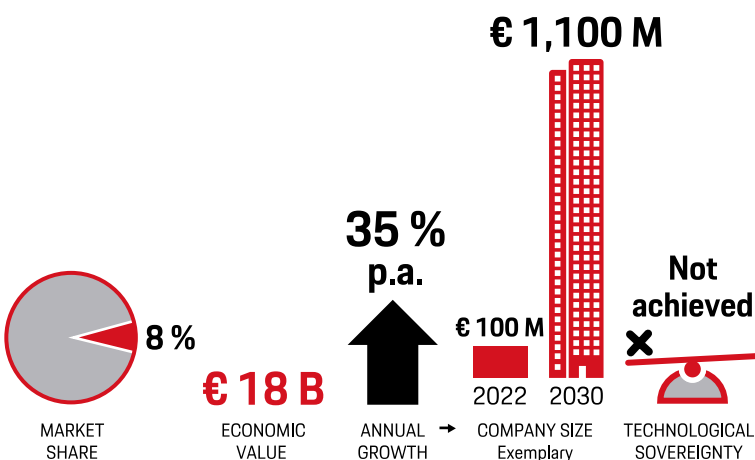
Settling for 8 %

Equipment manufacturers simply defending their current share of 8 % is also a possibility and still implies an ambitious goal of 35 % CAGR. A company with currently € 100 million in revenues would need to grow at least tenfold to become a € 1 billion business by the end of the decade. Given the shortages of skilled workers, we consider this an impossible trajectory unless equipment manufacturers follow the path of productization, and standardization described above.

Equipment manufacturing would stay in Asian hands, with Asian incumbents finally solving their internationalization problems and leaving European and North American followers in the dust. Individual European and North American equipment manufacturers might still enjoy technological advantages with select components, but the overall global share of the industry would hover around 8 %. Following this strategy would generate a mere € 18 billion in economic value by 2030.

Simulation of 8 % market share in 2030

Key figures based on model calculation.



© Porsche Consulting

Fig. 13. Scenario: Settling for 8 % market share in 2030.

SCENARIO C

Getting to 10 %

Below a 20 % global share, it is unlikely that Europe and North American Region can establish a second battery cell cluster; neither will it be able to claim technological sovereignty. Growing market share means to grow faster than Asia by opportunistically filling the internationalization gap left by the Asian incumbents. In this scenario, Europe and North America will be relegated to merely defending their market share as niche players supplying the factories of select followers. It would amount to continuing the status quo and by extension accepting Europe's and North America's second-tier role in the sector. Their overall share in Europe and North America would be capped below 20 %, while leaving the Asian market in more or less Asian hands. In total, global market share would barely rise to 10 % or € 22 billion, requiring a still steep CAGR of 38 % and outperforming the market. Besides the productization and standardization path required to maintain the 8 % market share, outpacing the market additionally requires a clear road map, harmonized interfaces, and strong alliances—and still would not be a walk in the park.

SCENARIO D

Leveraging technological sovereignty: aspiring to 30 %

Establishing technological sovereignty and a viable cluster with a minimum market share of 20 % means the cards would be reshuffled. This scenario makes it possible to benefit from the flywheel effect and reach new heights of 30–40 % market share. Aspiring to get to 30 % by 2030 means that technological sovereignty must be established well before the end of the decade, through superior innovation and through relevant market share among leaders and followers. At the same time, equipment manufacturers must achieve massive growth of 60–65 % CAGR.

Being at the forefront of innovation would make European equipment manufacturers attractive

suppliers for Asian leaders and followers, resulting in a global market share of 30 % and € 66 billion in value created through 2030.

SCENARIO E:
Reaching for 40 % and beyond

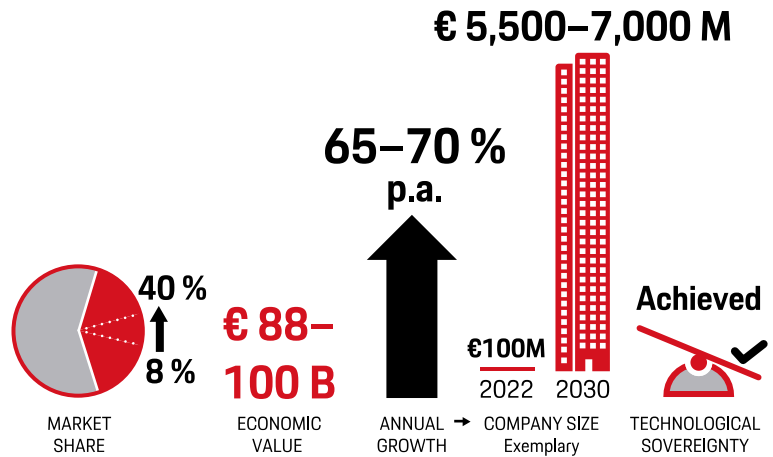
To get to 40 % market share or beyond, new European and North American champions need to emerge as the driving forces of the new cluster. This process can either happen by way of private businesses organizing themselves accordingly, by governments orchestrating its rise, or a combination of the two. Equipment manufacturers can form partnerships or joint ventures to secure the necessary financing for such large system integrators. Alternatively, investors or also governments can choose to assist with or orchestrate the formation of such champions for reasons of national interest and energy security, akin to the origin of Airbus in the aviation sector.

This sizable—if not very likely—market share can materialize if technological sovereignty, the 20 % ambition, a driving flywheel effect, and new, game-changing technology come together.

European companies would have to have checked all the boxes to first catch up and then outpace the Asian incumbents as outlined in Chapter 06. In total, a global market share of 40–45 % seems attainable, which translates into an overall volume of € 88–100 billion by 2030. Such a winning strategy would require the entire equipment manufacturing sector to grow at an almost insane CAGR of 65–70 % through the end of the decade. It would turn mid-sized € 100 million companies into players with revenues of about € 5.5 billion, able to scale beyond China's speed and solving all constraints that breakneck expansion brings with it.

The demands and customer needs of the booming battery industry fit well with the traditional strengths of European and North American equipment manufacturers. Providing the right machinery and process know-how to manufacture cells

Simulation of 40 % market share in 2030
Key figures based on model calculation.



© Porsche Consulting

Fig. 14. Scenario: Reaching for 40 % market share and beyond in 2030.

and produce modules and packs is one if not the crucial precondition for a viable battery ecosystem. Innovative and reliable machinery is also of paramount importance for transitioning to a more sustainable energy regime. Equipment manufacturers in Europe and North America hold the cards to make a second global battery cluster a reality—and they still have time to play them to catch up to and outpace the Asian competition.

Everyone wants and needs batteries, that much is certain—but who will be the one to build the machinery to produce them?

IN BRIEF

- 01** Western battery equipment manufacturers expect to have a 20 % global market share by 2030, representing a market opportunity worth €85 billion.
- 02** To surpass Asian competitors, it is essential for Europe and North America to collaborate on a unified roadmap, involving both battery OEMs and equipment manufacturers, as well as fostering cooperation among equipment manufacturers.
- 03** To manage the anticipated annual growth rates of 30 % or more, a different mindset is necessary. Initially, five critical steps must be undertaken to catch up in cost and scalability, followed by another five to pull ahead of the competition.
- 04** Case studies from various manufacturing sectors indicate that remarkable growth rates exceeding 50 % are achievable through the consistent application of productization and industrialization principles.

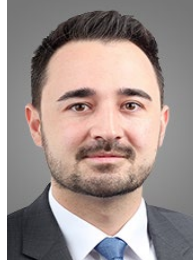
Authors



Gregor
Grandl
Senior Partner,
Porsche Consulting



Dr. Fabian
Duffner
Partner,
Porsche Consulting



Matthias
Baum
Associate Partner,
Porsche Consulting



Matthias
Möhrke
Associate Partner,
Porsche Consulting



Dr. Xiaohan
Wu
Lead Expert,
Porsche Consulting

▼
Contact
☎ + 49 170-911 3883



Dr. Sarah
Michaelis
VDMA Battery
Production



Bernd
Heitzmann
VDMA Robotics +
Automation

Contributors and Partners

Axel Bartmann (Manz AG),
Alexis Caballero (Festo Vertrieb GmbH & Co. KG),
Dr. Joachim Doehner (KUKA Systems GmbH),
Dr. Dominik Eckstein (Porsche Consulting),
Stephan Eirich (Maschinenfabrik Gustav Eirich GmbH & Co KG),
Bernd Feirabend (Robert Bosch GmbH Engineering and Production Services),
Sebastian Lemm (Porsche Consulting),
Dirk Pfitzer (Porsche Consulting),
Christoph Remmers (Porsche Consulting),
Enno Scharphuis (Bosch Rexroth AG),
Klaus Schrenker (MVTec Software GmbH),
Patrick Schwarzkopf (VDMA Robotics + Automation)

Sponsors



VDMA

With 3,600 member companies, the VDMA is the largest network organization and an important voice for the machinery and equipment manufacturing industry in Germany and Europe. The association represents the common economic, technical and scientific interests of this unique and diverse industry. VDMA Robotics + Automation stands for one of the most dynamic and fastest-growing sub-sectors of the mechanical engineering industry. It is made up of the three sector groups Robotics, Machine Vision and Integrated Assembly Solutions. Its 400 member companies are manufacturers of assembly and handling technology, machine vision and robotics. VDMA Battery Production unites 170 member companies addressing the production technology of batteries of all technologies but with a current focus on lithium-ion technology. Member companies supply machines, plants, components, tools and services along the entire process chain of battery production: from raw material preparation to electrode production and cell assembly to module and pack production.

Porsche Consulting

Porsche Consulting GmbH is a leading German management consultancy and employs 900 people worldwide. The company is a subsidiary of the sports car manufacturer Dr. Ing. h.c. F. Porsche AG, Stuttgart. Porsche Consulting has offices in Stuttgart, Hamburg, Munich, Berlin, Frankfurt am Main, Milan, Paris, São Paulo, Shanghai, Beijing, Atlanta, and Palo Alto. Following the principle of "Strategic vision. Smart implementation," the consultants advise industry leaders on strategy, innovation, brand, sales, development, technology, and operations. Porsche Consulting's worldwide network serves clients in the aerospace, automotive, construction, consumer goods, energy, financial services, industrial goods, life sciences, and transportation sector.



Appendix

References

- (1) Porsche Consulting Battery Market Model
- (2) Investment Announcements of Batteries OEMs & Investors; Internet Recherche
- (3) Porsche Consulting (2022): Understanding the Automotive Battery Life Cycle;
<https://www.porsche-consulting.com/international/en/publication/understanding-automotive-battery-life-cycle>
- (4) PEM RWTH Aachen University, BLB TU Braunschweig und VDMA (2021): Recycling von Lithium-Ionenbatterien;
<https://www.vdma.org/documents/34570/0/Brosch%C3%BCre%203-%20Batterierycycling.pdf/a3cdb33b-463d-bbc3-0e3a-c3dfadb55b0f>
- (5) Porsche Consulting Magazin (2023): The Race for Solid-State Batteries;
<https://magazine.porsche-consulting.com/en/the-race-for-solid-state-batteries/>
- (6) Online survey among cell OEM and equipment manufacturers, by Porsche Consulting (2023)
- (7) Structured personal interviews, by Porsche Consulting (2023)
- (8) Confidence level index "battery production", by Porsche Consulting & VDMA at annual conference Steinhagen (2023)
- (9) VDMA (2022): EU-Reaktion auf den Inflation Reduction Act im Bereich der Klima-Transformationstechnologien;
<https://www.vdma.org/documents/34570/4802302/2023-03+VDMA+K%26E+EU-KlimaIndustrie+Diskussionspapier.pdf/c3c3dbe8-b0cc-fb6f-8a45-8b3bc49271bf?t=1678440126098>

Glossary

BEV	Battery Electric Vehicle
CAGR	Compound Annual Growth Rate
Gigafactory	Cell factories with output > 1 GWh
GWh	Gigawatt hours
kWh	Kilowatt hours
Megafactory	Smaller factories with specialized boutique character
OEM	Original Equipment Manufacturer
OEE	Overall Equipment Efficiency
ROI	Return on Investment
TCO	Total Cost of Ownership
VDMA	Verband Deutscher Maschinen- und Anlagenbau e. V.



**“WE CANNOT
CHANGE THE
WIND, BUT
WE CAN SET
THE SAILS
DIFFERENTLY.”**

Aristotle

Porsche Consulting

Stuttgart | Hamburg | Munich | Berlin | Frankfurt | Milan | Paris | São Paulo | Atlanta | Palo Alto | Shanghai | Beijing

www.porsche-consulting.com

© Porsche Consulting 2024